OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
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9. Remarks

Revision History

10. Revision No.	11. Description of Revision
REV 00	Initial Issue
REV 01	Updated reference format throughout text; added a Reference section (Section 8); deleted Attachment I - DIRS; incorporated non-involved worker dose calculations (Attachment V); revised frequency of collision (See Addendum 1)
REV 01 ICN 01	Revised Assumption 3.1; added EPA (1980) and Podolak et al. (1988) references. Regarding this ICN, Attachment I and Attachments V through XI of this technical product contain documentation of single-use (See Addendum 2)
REV 01 ICN 02	Changed title in block 2 of this page to add "Event". Revised title is "Design Basis Event Frequency and Dose Calculation for Site Recommendation." No changes to any other text or calculation.

Addendum 1

events (Attachment VII) and equipment drops onto SNF (Attachment VI); added calculations for two new non-mechanistic events; added software validation test cases to Attachments V, VII, VIII, IX and X; added discussion of exposure time for Category 1 and 2 events; incorporated various editorial changes and clarifications; made minor technical corrections that did not impact the results; revised submersion dose coefficients in Attachment VIII to reflect the units and values in Federal Guidance Report #12 (Eckerman and Ryman 1993); added Attachment I.

Addendum 2

software routines that were qualified under procedure AP-SI.1Q, Software Management, prior to the release of Rev. 3 of said procedure. As the scope of this ICN did not involve a change to either the routine codes or associated documentation, and they have not been used to develop additional quality affecting information, or to modify data in this ICN, these single-use software routines will remain documented herein, in accordance with AP-SI.1Q, prior to the release of Rev. 3.

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1. PURPOSE

The purpose of this document is to calculate event sequence frequencies and consequences of design basis events (DBEs) at the Monitored Geologic Repository (MGR). The frequency assessment determines whether an event sequence is classified as a Category 1 or Category 2 DBE, per the definition in the proposed 10 CFR 63.2 (Dyer 1999). The consequence analysis for Category 1 and Category 2 DBEs includes both non-involved worker and public doses and provides a basis for comparison with worker and public dose limits specified in 10 CFR 20 and 10 CFR 63.111 (Dyer 1999), respectively. The results of this calculation will be used to support the Site Recommendation Preclosure Safety Assessment. The work scope for Revision 1 was performed in accordance with procedure AP-3.12Q, *Calculations*, and the approved development plan (CRWMS M&O 1999j) for this activity. The work scope for Revision 1, ICN 1 was performed in accordance with procedure AP-3.12Q, *Calculations*, and the approved technical work plan (CRWMS M&O 2000g) for this activity.

The scope of this calculation is limited to DBEs involving commercial spent nuclear fuel (CSNF). Commercial mixed oxide (MOX) spent fuel was considered separately and compared to CSNF in Attachment XI.

The dose assessment provided in this calculation is limited to credible event sequences that have the potential to result in a radiological release. Credible, for the purpose of this calculation, is defined as an event sequence expected to occur at least once per million years (i.e., having an event frequency $\geq 10^{-6}$ per year). The *Preliminary Selection of MGR Design Basis Events* (CRWMS M&O 1999g) evaluated a broader range of event sequences including external events (e.g., earthquake- and tornado-initiated events), internal events with no release, and event sequences categorized as "beyond design basis" (i.e., event frequencies $<10^{-6}$ per year). Potential events considered in this calculation include unsealed shipping cask handling events, CSNF assembly and assembly basket handling events, unsealed disposal container (DC) handling events, and "early failure" of a waste package (WP) in the preclosure period.

2. METHOD

2.1 FREQUENCY CALCULATIONS

An event sequence frequency is defined as the product of an initiating event frequency and the conditional probabilities of all subsequent events leading to a final event sequence. In this calculation, all final events involve a ground-level radiological release (Assumption 3.25) from either the waste handling building (WHB) or the subsurface facility. A typical event sequence calculation is shown below:

$$f_i \times P_1 \times P_2 \times ... P_n = f_f \quad (1)$$

where,

f_i = initiating event frequency (events/year)

$P_1, P_2, .. P_n$ = conditional probability (dimensionless) of events 1,2,..n

f_f = final event sequence frequency (events/year)

Event sequence frequencies for potential events associated with waste handling and storage activities at the MGR are listed in Attachment VII. The frequency category for each event sequence was calculated based on the definition of design basis events from 10 CFR 63 (Dyer 1999), as shown in Table 1 below:

Table 1 – Definition of Design Basis Event Categories

DBE Category	Event Sequence Frequency, *f**	Definition
1	$f \geq 10^{-2}$/yr	*"Those natural events and human-induced event sequences that are expected to occur one or more times before permanent closure of the geologic repository operations area (referred to as Category 1 events)"*
2	10^{-6}/yr $\leq f < 10^{-2}$/yr	*"(a) Other human-induced event sequences that have at least one chance in 10,000 of occurring before permanent closure of the geologic repository, and (b) appropriate consideration of natural events (phenomena) that have been historically reported for the site and the geologic setting (referred to as Category 2 events).*
BDBE	$f < 10^{-6}$/yr	Beyond Design Basis Events (BDBE) are defined herein as those event sequences that have less than one chance in 10,000 of occurring before permanent closure. Note: this definition is not found in 10 CFR 63 (Dyer 1999).

* Cutoff frequencies of 10^{-6}/yr and 10^{-2}/yr are based on an assumed 100-year preclosure period (see Assumption 3.27).

2.2 DOSE CALCULATIONS

The objective of this calculation is to calculate offsite doses for Category 1 and Category 2 DBEs. Since the regulatory limit for Category 2 DBEs is a total effective dose equivalent (TEDE) of 5 rem per event (Dyer 1999), the doses due to Category 2 events are calculated on a per event basis. The regulatory limit for Category 1 events is a TEDE of 25 mrem per year (Dyer 1999). Therefore, all Category 1 event doses are calculated on a per year basis. This calculation does not compare the results with the limits, it merely presents the offsite dose results for a given set of design basis events and normal operational releases.

The four dose measures applicable to Category 2 DBEs at the MGR are identified below:

- Total effective dose equivalent (TEDE). The TEDE is equal to the committed effective dose equivalent (CEDE), commonly referred to as the "whole body dose," plus the deep dose equivalent (DDE) per the definition in 10 CFR 20, Section 1003. The CEDE is calculated using the "effective" inhalation dose conversion factor (DCF). The DDE is calculated using the "effective" air submersion DCF. For Category 1 events, TEDE dose also includes ingestion and ground surface doses, in addition to inhalation and submersion doses.

- Highest of the committed dose equivalents (CDEs) plus the DDE. The organs evaluated to determine the highest CDE are the lungs, breasts, gonads, bone marrow, bone surface, thyroid, and remainder. The "remainder" is not an organ, but rather a weighted combination of the five remaining organs or tissues (such as liver, kidneys, spleen, brain, etc., but excluding skin, lens of the eye, and the extremities) receiving the highest doses (Eckerman et al. 1988). The DDE which is added to the highest CDE is equal to that used to calculate the TEDE, per the definition of DDE in 10 CFR 20.

- Lens of the Eye. Applies to the external exposure of the lens of the eye and is taken as the dose equivalent at a tissue depth of 0.3 centimeter. The LDE was not calculated because Kr-83m is the only nuclide having a submersion exposure-to-dose conversion factor listed for lens of the eye in Eckerman et al. (1988) and the Kr-83m source term is negligible because of its short half-life (1.8 hours) and the minimum decay time (5 years) for SNF handled at the MGR.

- Skin & Extremities. Applies to the dose to the skin and extremities due to the air submersion pathway.

Out of the four dose measures shown above, only the TEDE dose measure is applicable to Category 1 DBEs.

Category 1 Events. The Category 1 dose is based on the annual exposure to a hypothetical subsistence farmer living at the site boundary (see Attachment IV, Section 2.2). Dose calculations for Category 1 events consider the inhalation, ingestion, submersion, and groundshine exposure pathways. Category 1 doses were calculated with the GENII-S Code (CRWMS M&O 1998c) using the methodology discussed in Attachment IV.

The total Category 1 annual dose is based on contributions from three sources: Category 1 DBEs, normal operational (routine) releases from the WHB, and normal operational releases from the subsurface repository. The total Category 1 annual dose (mrem/yr) is generally described by the following equation:

$$D_{Cat.1}^{TOT} = D_{Cat.1}^{DBEs} + D_{NO}^{WHB} + D_{NO}^{Sub} \quad (2)$$

where,

$D_{Cat.1}^{DBEs}$ = Annual dose due to all Category 1 DBE releases [mrem/yr]

D_{NO}^{WHB} = Annual dose due to normal operational releases from the WHB [mrem/yr]

D_{NO}^{Sub} = Annual dose due to normal operational releases from the subsurface repository [mrem/yr]

The radiological release (Ci/yr) estimates for each of these components were used as an input to the GENII-S dose calculation. The annual release due to normal operations in the WHB and normal operations in the subsurface repository were obtained via AP-3.14Q input transmittals (CRWMS M&O 2000a and 2000b). The annual release due to all Category 1 events was calculated based on the following equation:

$$R_{DBEs}^{TOT} = \sum_{i=1}^{n} R_i^{DBE} \cdot f_i \quad (3)$$

where,

i = Index for a given Category 1 event sequence (i = 1,2,...n)
n = Total number of Category 1 event sequences

R_i^{DBE} = Radiological release due to event sequence i [Ci/event]

f_i = Frequency of event sequence i [events/yr]

Input parameters and results of the GENII-S dose assessment for Category 1 events are provided in Attachment IV and summarized in Section 6.

Category 2 Events. Category 2 events are assumed to release a ground-level radioactive plume which is dispersed enroute to the site boundary and results in an 8-hr acute individual exposure. Only the inhalation and air submersion exposure pathways are considered for Category 2 DBEs because of the short term exposure. The potential doses from ingestion, water immersion, and contaminated soil are assumed to be negligible for acute exposures (Assumptions 3.1 and 3.5).

The TEDE dose measure is expressed as:

$$TEDE = \sum_j D_{j,effective}^{inh} + \sum_j D_{j,effective}^{sub} \quad (4)$$

where,

$D_{j,effective}^{inh}$ = Whole body "effective" inhalation dose [rem] from the j^{th} isotope, also referred to as the CEDE.

$D_{j,effective}^{sub}$ = Whole body "effective" submersion dose [rem] from the j^{th} isotope, also referred to as the DDE.

The maximum CDE+DDE dose measure is expressed as:

$$CDE_k + DDE = \sum_j D_{j,k}^{inh} + \sum_j D_{j,k}^{sub} \quad (5)$$

where,

CDE_k = Committed dose equivalent to the k^{th} organ [rem]

$D_{j,k}^{inh}$ = Radiation dose from the j^{th} isotope to the k^{th} "organ" due to inhalation [rem]

$D_{j,k}^{sub}$ = Radiation dose from the j^{th} isotope to the k^{th} "organ" due to air submersion [rem]

k = "Organ" index, where "organs" are gonads, breast, lungs, bone marrow, bone surface, thyroid, and remainder†

† The remainder represents the next five remaining organs or tissues (such as liver, kidneys, spleen, brain, small intestine, upper large intestine, lower large intestine, etc., but excluding the skin, lens of the eye, and the extremities) receiving the highest doses (Eckerman et al. 1988).

The inhalation and air submersion doses shown above can be further expressed as:

$$D_{j,k}^{inh} = ST_j \times FA \times \frac{\chi}{Q} \times BR \times conv \times DCF_{j,k}^{inh} \quad (6)$$

$$D_{j,k}^{sub} = ST_j \times FA \times \frac{\chi}{Q} \times conv \times DCF_{j,k}^{sub} \quad (7)$$

where,

ST_j = Inventory source term release per fuel assembly (FA) for the j^{th} isotope[Ci/FA]

FA = Number of fuel assemblies involved in the release [# FAs]

$\frac{\chi}{Q}$ = Atmospheric dispersion factor [s/m^3]

BR = Breathing rate [m^3/s]

$DCF_{j,k}^{inh}$ = Inhalation dose conversion factor of the j^{th} isotope for the k^{th} organ [Sv/Bq] (Eckerman et al. 1988)

$DCF_{j,k}^{sub}$ = Air submersion dose coefficient of the j^{th} isotope for the k^{th} organ [(Sv-m^3)/(Bq-s)] (Eckerman and Ryman 1993)

$conv$ = DCF unit conversion factor: 3.7×10^{12} (rem-Bq)/(Ci-Sv) (Eckerman et al. 1988)

The skin dose is equal to

$$SKIN = \sum_j D_{j,skin}^{sub} \quad (8)$$

where,

$SKIN$ = Dose to the skin [rem]

$D_{j,skin}^{sub}$ = Radiation dose from the j^{th} isotope to the skin due to air submersion [rem]

2.2.1 Source Terms for Commercial Spent Nuclear Fuel

Source terms for PWR and Boiling Water Reactor (BWR) CSNF used in this calculation were extracted from *PWR Source Term Generation and Evaluation* (CRWMS M&O 1999h) and *BWR Source Term Generation and Evaluation* (CRWMS M&O 1999b). Source terms for PWR and BWR spent fuel assemblies (SFAs) with four different combinations of initial enrichment, burnup, and decay time were considered:

Average PWR assembly: 4.0%, 48 GWd/MTU, 25 years
Maximum PWR assembly: 5.0%, 75 GWd/MTU, 5 years
Average BWR assembly: 3.5%, 40 GWd/MTU, 25 years
Maximum BWR assembly: 5.0%, 75 GWd/MTU, 5 years

Average PWR fuel was selected for consequence analysis of all Category 1 events because it was found to result in a higher offsite dose consequence as compared to Average BWR fuel. This result is generally attributed to the higher enrichment, burnup, and concentration of radioactive gases and actinides in PWR fuel.

For Category 2 events, either the Maximum PWR fuel or the Maximum BWR fuel was used for dose assessment, depending on which source term resulted in the highest event dose. For events occurring in the pool, Maximum PWR fuel results in the largest offsite dose due to the larger inventory of radioactive gases compared to Maximum BWR fuel. For events involving particulate releases in a dry environment (e.g., hot cell), however, the Maximum BWR fuel results in a larger offsite dose than Maximum PWR fuel because of the increased crud inventory. Crud dominates the offsite dose for dry events because of the very conservative release fractions (see Section 5.2.12) and decay time used. The largest potential dose for each event analyzed is the dose reported in Section 6 of this calculation. Radionuclide inventories (Curies/FA) and normalized inhalation doses (Rem/FA) to each organ, for each nuclide and fuel type evaluated, are included in Attachment VIII.

A comparison of high burnup PWR Mixed Oxide (MOX) fuel versus the maximum PWR fuel used in Category 2 dose assessment is provided in Attachment XI. The high burnup MOX fuel is based on radionuclide activities cited in the *Draft Environmental Impact Statement (EIS) for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE 1999).

Crud: Crud is a corrosion product that has been found on the exterior surface of spent nuclear fuel assemblies due to irradiation and imperfect water chemistry control in the reactor coolant system. Crud can be released to the environment during a DBE involving CSNF at the potential repository.

This calculation considered the crud activity of Fe-55 and Co-60. Crud activities used for the average and maximum PWR and BWR assemblies were based on values recommended in *Commercial SNF Accident Release Fractions* (CRWMS M&O 1999d). Refer to Input Parameters 5.2.7 and 5.2.6 for the Fe-55 and Co-60 surface activities and fuel assembly surface areas, respectively, which were used to calculate inhalation doses.

The crud source term (Curies/FA) released to the environment, on a per assembly basis, is calculated as follows:

$$ST_{crud} = SA_{crud} \times A_{SFA} \times conv \tag{9}$$

where,

ST_{crud} = Crud source term [Ci/FA]
SA_{crud} = Crud surface activity per assembly [μCi/cm^2]
A_{SFA} = Surface area per assembly [cm^2/FA)
$conv$ = Conversion factor [10^{-6} Ci/μCi]

The crud surface activity for a given fuel assembly is a function of time after discharge from the reactor. The time-dependent crud surface activity is based on the radioactive decay equation (CRWMS M&O 1999h) as follows:

$$N(t) = N(0)e^{\frac{-t*\ln 2}{t_{1/2}}} \tag{10}$$

where,

$SA_{crud} \equiv N(t)$

N(0) = Initial crud surface activity per assembly at time of discharge from the reactor [$\mu Ci/cm^2$]
t = Time since discharge from the reactor [yrs]
$t_{1/2}$ = Radioisotope (Co-60 or Fe-55) half life [yrs]

Crud source terms for both Category 1 events are based on Average PWR fuel with a 25-year decay. The crud source term for Category 2 events is based on the maximum PWR or BWR fuel with a 5 year decay time. Crud source terms for Category 1 events are shown in Attachment IX. Crud source terms for Category 2 DBEs are included in Attachment X.

Because of the relatively short decay period (5 years) assumed for the maximum PWR and BWR SFAs, crud is a significant contributor to the inhalation dose at the site boundary (see Attachment X). On average, crud is responsible for 78% of the total whole body inhalation dose for a dry event (as opposed to a pool event) involving the breach of 44 BWR SFAs (Attachment X).

2.2.2 Release Fractions

The total release fraction is defined as the fraction of total inventory of a given radionuclide that is released to the environment from a waste form. The release fraction for CSNF is primarily a measure of the inventory of fuel particulates, gases and volatile species present in the fuel-cladding gap region of each breached fuel rod. An illustration of the structure of a typical commercial SNF assembly is provided in Figure 1.

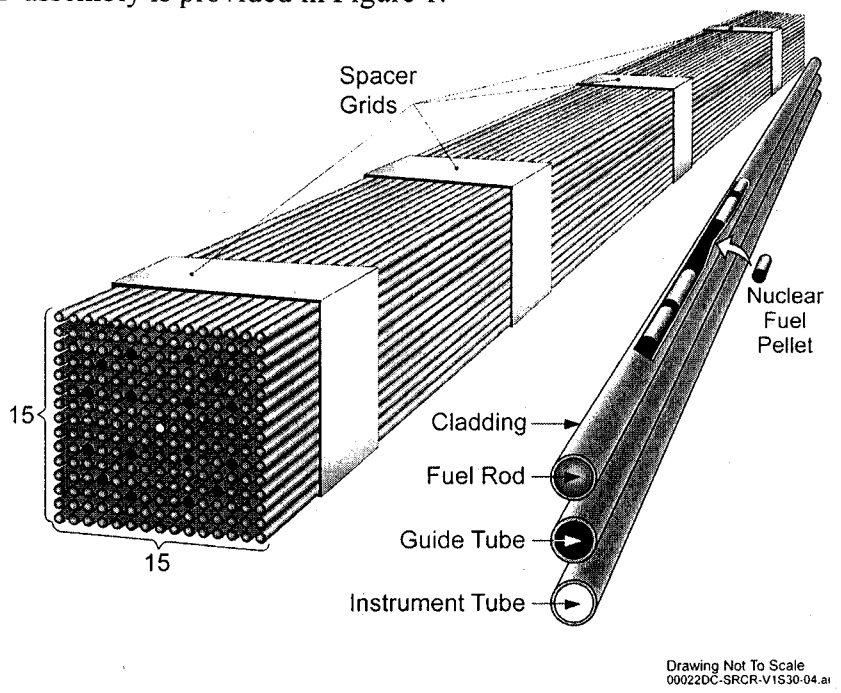

Figure 1. Typical Commercial SNF Assembly

The total release fraction for calculating the source term released from Category 1 and Category 2 events is a function of the cladding damage fraction (DF), cladding release fraction (CR), airborne release fraction (ARF), respirable fraction (RF), and the local deposition factor (DEP):

$$Total\ Release\ Fraction = DF \times CR \times ARF \times RF \times DEP \quad (11)$$

The DF is the fraction of fuel rods that are assumed to fail by cladding breach during a design basis event. The CR is the fraction of the total radionuclide inventory in the fuel-cladding gap that is released from the fuel rod and available for transport. The ARF is the fraction of radioactive material that is suspended in air as an aerosol following a discrete event and available for transport. The RF is the fraction of airborne radionuclide particles having an Aerodynamic Equivalent Dyameter (AED) of 10-μm and less, which can be transported through air, inhaled into the human respiratory system, and contribute to the inhalation dose. The DEP is the fraction of the ARF that is deposited locally within the WHB, prior to reaching the ventilation system HEPA filters.

For this calculation, the DF, CR, and DEP fractions were all set to unity (Assumption 3.20). This is a relatively conservative assumption since each of these factors is expected to provide some reduction in the total release fraction in the event of a radiological release. A DEP factor of 1.0 implies that there is no local deposition or gravitational settling of radioactive particles on surfaces in the building.

The ARF and RF parameters (Section 5.2.12) for Category 1 and 2 events involving CSNF releases in air are based on *Commercial SNF Accident Release Fractions* (CRWMS M&O 1999d), with an exception for Category 1 releases in air. In this case, a RF of 1.0 is assumed (Assumption 3.24) in order to include all particle sizes in the dose calculation for the ingestion pathway.

For events occurring in a pool, an ARF equal to zero is assumed (Assumption 3.21) for all particulates and volatiles. In pool events, only the noble gases are released from the pool. The release fractions for CSNF releases in air and water for Category 1 and Category 2 dose assessments are shown in Attachment IX and Attachment X, respectively.

2.2.3 Atmospheric Dispersion Factors (χ/Q)

Atmospheric dispersion factors used in this calculation were extracted from *Calculations of Acute and Chronic "Chi/Q" Dispersion Estimates for a Surface Release* (CRWMS M&O 1999c). Category 1 event releases are modeled as "chronic" releases and use the maximum sector chronic χ/Q at the distances evaluated. Category 2 event releases are modeled as "acute" releases and use the maximum sector 99.5 percentile acute (0.5% exceedance) χ/Q values for the distances evaluated. The selection of the maximum sector 99.5% χ/Q value is based on it being larger than the 95% overall site χ/Q value, per Regulatory Guide 1.145.

The acute exposure χ/Q value is based on a 2-hour exposure at Exclusion Area Boundary distances (Regulatory Guide 1.145), which corresponds to the site boundary for the purpose of this calculation. The chronic exposure χ/Q is based on the annual average, best-estimate

exposure at a given distance, per Regulatory Guide 1.111. Stack releases are not assumed in either the acute or chronic χ/Q calculations (CRWMS M&O 1999c).

A site boundary distance of 11-km was assumed (Assumption 3.3) to calculate doses due to radiological releases from the WHB. This distance corresponds to the distance from the MGR WHB ventilation exhaust shaft to the nearest point on the proposed YMP Withdrawal Area boundary (to the West), the closest point that any member of the public could be standing or living at the time of a postulated radiological release (see Attachment III). It is assumed that no persons will be allowed to live within the YMP Withdrawal Area and that administrative controls will be in place to evacuate any members of the public that could potentially be located within the YMP Withdrawal Area but outside of the Preclosure Controlled Area Boundary (Attachment III) following a Category 2 DBE.

A site boundary distance of 8-km was assumed (Assumption 3.3) to calculate potential doses due to radiological releases from the subsurface repository. This distance corresponds to the approximate distance between the potential repository and the nearest point of public access on the proposed YMP Withdrawal Area boundary (to the West, see Attachment III).

A distance of 100-m was assumed (Assumption 3.3) to calculate the annual Category 1 dose to workers at the MGR. This distance is consistent with the distance used to calculate the radiation dose to a non-involved worker in the draft EIS (DOE 1999, Appendix H).

2.2.4 Breathing Rate

For calculating offsite doses due to acute releases (Category 2 DBEs), a worker breathing rate of 3.3×10^{-4} m^3/s was utilized (NRC 1997). For chronic releases, the default breathing rate for reasonable representation cases is 2.662×10^{-4} m^3/s (266.2 cm^3/s)(Attachment IV, Figure 2). The chronic breathing rate is used to calculate Category 1 offsite doses.

2.2.5 Mitigation Factor

The mitigation factor used in this calculation refers to the filtration of particulates provided by High Efficiency Particulate Air (HEPA) filters that are present in the WHB design (CRWMS M&O 2000d). A HEPA mitigation factor of 0.01 (Assumption 3.23) was applied to all particulate releases to calculate offsite doses in Attachments IX and X. The mitigation factor of 0.01 corresponds to a particulate removal efficiency of 99%, which is consistent with the NRC-recommended credit for accident dose evaluations in Regulatory Guides 1.52 and 1.140.

Due to the high reliability of the WHB Heating, Ventilation and Air Conditioning (HVAC) system (CRWMS M&O 1999i), all event sequences that involved a failure of the HVAC system were found to be beyond design basis. Dose results for mitigated Category 1 and Category 2 releases are presented in Section 6.1.

2.2.6 Dose Conversion Factors

Dose conversion factors for inhalation are dependent on the chemical form of the radionuclide, which is represented by the lung clearance class (D=daily, W=weekly, Y= yearly) and the

fractional uptake from the small intestine to blood (f_1). Some isotopes have only one lung clearance class (e.g., H-3), whereas others have multiple lung clearance classes (e.g., Pu-239). For Category 2 inhalation dose assessment of radionuclides with multiple lung clearance classes, the lung clearance class corresponding to the oxide form of the radionuclide (Eckerman et al. 1988) was assumed (Assumption 3.4). The inhalation DCFs utilized for Category 2 dose assessment are from Table 2.1 of Federal Guidance Report No.11 (Eckerman et al. 1988). The air submersion dose coefficients for Category 2 dose assessment are from Table III.1 of Federal Guidance Report No. 12 (Eckerman and Ryman 1993). The inhalation and submersion DCFs used for Category 2 dose assessment are included in Attachment VIII.

For Category 1 dose assessment, inhalation DCFs are derived by the GENII-S code based on dosimetric methodology from International Commission on Radiological Protection (ICRP) Publication 30 (ICRP 1979). In cases where multiple lung clearance classes are available, GENII-S selects the Class that results in the largest Effective DCF value. This is a very conservative approach and adds conservatism to the Category 1 dose calculations. For a more thorough discussion of the conservatism associated with inhalation DCFs for Category 1 dose calculations, refer to Section 6.3.

External DCFs for air submersion, water surface, soil surface, deep soil, and buried waste, used by GENII-S to calculate doses for Category 1 events, are taken from input file GRDF.15 (Attachment IV, Figure 3). This file is a modification to the original GENII-S input file GRDF.DAT, and incorporates the latest data from Federal Guidance Report No. 12 (Eckerman and Ryman 1993) and DTN: MO9912RIB00066.000.

Internal and external dose conversion factors used in GENII-S were evaluated in *Dose Conversion Factor Analysis: Evaluation of GENII-S Dose Assessment Methods* (CRWMS M&O 1999e). This analysis found that, as compared to Federal Guidance Report No. 11 (Eckerman et al. 1988), GENII-S overestimates internal doses from some radionuclides and underestimates internal doses from others, but concluded that the differences are acceptable considering the level of uncertainties inherent in the dose assessment process.

3. ASSUMPTIONS

The following assumptions are used in this calculation.

3.1 Only inhalation and air submersion doses are considered in calculating offsite doses from Category 2 events. The ingestion pathway, if it occurs, is a slow-to-develop pathway and is not considered an immediate threat to an exposed population in the same sense as airborne plume exposures. Therefore, the ingestion pathway is not included in the calculation of the radiological doses resulting from Category 2 events for comparison against the risk acceptance criteria.

Basis: Exposure through the ingestion pathway occurs when radioactive materials that have been deposited offsite are ingested, either by eating crops grown in contaminated soil, or through inadvertent ingestion of trace amounts of contaminated soil, or through ingestion of contaminated drinking water. Potential doses from the ingestion pathway are not included in the comparison to 10 CFR 63 dose limits because during the preclosure

operations period there would be interdiction programs in place (to be established in a DOE emergency response program) to prevent the ingestion of contaminated food and water in the event of a Category 2 event. The U.S. Environmental Protection Agency provides Protective Action Guides for radiological protection guidance for federal, state, and local government in the *Manual of Protective Actions for Nuclear Incidents* (EPA 1980) that may be used for responding to a nuclear incident or radiological emergency. Protective Action Guides are defined as the projected dose to a standard man from an unplanned release of radioactive material at which a specific protective action to reduce or avoid that dose is warranted. The protective actions recommended to avoid or reduce the radiation dose are based on exposure pathway (inhalation, plume, ground deposition) and incident phase (early, intermediate, late). The *Criteria for Preparation and Evaluation of Radiological Response Plans and Preparedness in Support of Nuclear Power Plants* (Pololak et al. 1988) provides a basis for NRC licensees and state and local governments to develop radiological response plans and improve emergency preparedness. In this report it is stated that the basis for the choice of protective actions will be established. Further, the protective measures to be used will be established for the ingestion pathway, including the methods of protecting the public from consumption of contaminated foodstuffs. It is also stated that the plan shall identify procedures for detecting contamination, for estimating the dose commitment consequences of uncontrolled ingestion, and for imposing protection procedures such as impoundment, decontamination, processing, decay, product diversion, and preservation. Category 2 events result in acute releases over a period of a few hours and the doses from these pathways (i.e., ingestion via crops, soil, or water) may be controlled by interdiction as needed, thus precluding ingestion, water immersion and contaminated soil (groundshine) source term pathways.

This assumption is used in Section 2.2. This assumption does not require further confirmation because it has a minimal impact on the calculation results.

Input Status: N/A – Not Critical.

3.2 The total radiological release due to a single-element canister containing non-intact fuel rods, referred to as "failed fuel," is bounded by the radiological release of a PWR assembly with the following characteristics: 5.0% initial enrichment, 75 GWd/MTU burnup, and 5 year decay period.

Basis: Failed fuel contained in Single Element Canisters (SECs) is projected to account for less than 2% of the total number of SFAs and SECs handled per year at the MGR (Attachment VII). Furthermore, only a portion of the entire failed fuel inventory will consist of intact fuel rods that could potentially fail during a design basis event and release a source term comparable to intact CSNF assemblies. Most of the projected failed fuel consists of cladding-damaged SNF, fuel pieces, fuel debris, and non-fuel components, which have likely already released any radioactive gases and particulates in the fuel-cladding gap. Projected quantities and characteristics of failed fuel are from *1999 Design Basis Waste Input Report for Commercial Spent Nuclear Fuel* (CRWMS M&O 1999a).

This assumption is used in Attachments IX and X. This assumption does not require further confirmation because it has a minimal impact on the calculation results.

Input Status: N/A – Not Critical.

3.3 The public dose receptor is located at a distance of either 8 kilometers (km) or 11 km, depending on whether the release point is from the subsurface or surface facility, and the non-involved worker is located at a distance of 100 meters from the release point.

Basis: The distance between the Waste Handling Building and the nearest point of public access on the proposed YMP Withdrawal Area boundary (to the West) is 11.65 kilometers (Attachment III, MO0001YMP00001.000). The distance between the westernmost point of the proposed Yucca Mountain repository and the nearest point of public access on the proposed YMP Withdrawal Area boundary (to the West) is approximately 8 km (Attachment III, MO0001YMP00001.000). Other points on the proposed YMP Withdrawal Area boundary which are closer to the WHB are on either Nevada Test Site or Nellis Air Force Base property where public access is prohibited.

The public dose receptor distances are conservatively selected to maximize the offsite dose consequences for the purpose of this calculation. The non-involved worker distance is based on the calculation distance for non-involved workers presented in the draft EIS for the MGR (DOE 1999, Appendix H).

This assumption is used in Attachments IV, V and X. This assumption does not require further confirmation because the calculation results are relatively insensitive (compared to other parameters) to the "Chi/Q" associated with the public and worker dose receptor distances.

Input Status: N/A – Not Critical.

3.4 For isotopes with multiple clearance classes, the lung clearance class that corresponds to the oxide form of the radionuclide (Eckerman et al. 1988) is assumed.

Basis: The majority of the CSNF to be processed at the MGR is expected to be in the oxide form. In some cases (e.g., Plutonium radionuclides), the lung clearance class associated with the nitrate or other chemical form of the radionuclide results in a higher DCF value. Overall, however, the quanitity of CSNF falling into this category is negligible and the cumulative impact on the dose results is minimal.

This assumption is used in Attachment VIII. This assumption does not require further confirmation because it has a minimal impact on the calculation results.

Input Status: N/A – Not Critical.

3.5 The Deep Dose Equivalent (DDE) dose is equal to the effective dose equivalent from air submersion; the external dose contribution from water immersion and contaminated soil is negligible.

Basis: This assumption implies that these doses are negligible in comparison to the combined inhalation and air submersion dose and/or the doses from these pathways may be controlled by interdiction as needed, thus precluding these source term pathways.

This assumption is used in Section 2.2. This assumption does not require further confirmation because it has a minimal impact on the calculation results.

Input Status: N/A – Not Critical.

3.6 Each DC processed at the MGR is lifted only once while in the unsealed condition – from the transfer cart to the welding station turntable.

Basis: The *Surface Design Description for Site Recommendation* (CRWMS M&O 2000d) allow for the option to stage unsealed DCs in the DC staging area under off-normal conditions when all of the welding stations are either occupied or under repair. This calculation assumes that there will be no lag storage of unsealed DCs. This assumption potentially impacts the unsealed DC drop event (Attachment VII, Event 2-09) because it is less than a factor of two below the cutoff frequency for Category 1 events (i.e., doubling the number of lifts would change the frequency category from Category 2 to Category 1).

This assumption is used in Attachment VII to calculate the frequency of an unsealed DC drop. This assumption requires confirmation before the frequency results associated with the unsealed DC drop/slapdown event can be qualified.

Input Status: Unqualified.

3.7 The maximum number of CSNF DCs processed in any single year is 600.

Basis: This number is expected to be bounding for CSNF based on evaluation of the current waste stream (CRWMS M&O 1999a). Based on the quantity and distribution of CSNF WPs (truncated case) from *WP and DOE Canister Inventory* (CRWMS M&O 2000e), a total of 10,011 CSNF WPs are expected to be processed at the MGR. Using an assumed operational period of 30 years (Assumption 3.12), this corresponds to an average throughput of 334 WPs per year. Applying a factor of 1.5 to account for the difference between the average year and the peak year yields a throughput of 501 WPs per year, which is 20% below the maximum number assumed in this calculation. Therefore, this assumption is considered conservative.

This assumption is used in Attachment VII to calculate the event frequencies associated with an unsealed DC. This assumption requires confirmation before the frequency results associated with the unsealed DC events (Attachment VII, Events 2-04 through 2-06) can be qualified.

Input Status: Unqualified.

3.8 Single element canisters (SECs) are handled similar to typical PWR assemblies, i.e., four (4) SECs are placed in an assembly basket.

Basis: Assuming four SECs are placed in a basket instead of 8 (i.e., treated like PWR SFAs instead of BWR SFAs) is conservative because it maximizes the number of baskets handled.

This assumption is used to calculate SFA basket event frequencies in Attachment VII. This assumption does not require further confirmation because the total number of SECs compared to the total number of CSNF SFAs is small and the event frequencies for basket handling events are already in the highest frequency category (Category 1). The impact on Category 1 event consequences is also negligible.

Input Status: N/A – Not Critical.

3.9 There are four (4) lifts per individual SFA. Two of these lifts are assumed to occur in the pool (out of the cask and into the basket staging rack) and two are assumed to occur in the hot cell (out of the dryer and into the DC).

Basis: This assumption is based on ATS design and operations, as described in the *Surface Design Description for Site Recommendation* (CRWMS M&O 2000d).

This assumption is used to calculate event frequencies in Attachment VII. This assumption requires confirmation before the frequency and dose results associated with SFA events (Attachments VII and IX) can be qualified.

Input Status: Unqualified.

3.10 Each CSNF basket handled at the MGR is lifted a maximum of six (6) times, including one (1) basket lift in the hot cell (out of the Wet Assembly Transfer Machine and into the dryer) and five (5) basket lifts in or over the pool. The following basket lifts in the pool are assumed:

(1) Out of the basket staging rack and onto a transfer cart
(2) Off the transfer cart and into pool storage
(3) Out of pool storage and onto the transfer cart
(4) Off the transfer cart and into the Incline Transfer Cart
(5) Off the Incline Transfer Cart and into the Wet Assembly Transfer Machine

Basis: This assumption is based on ATS design and operations, as described in the *Surface Design Description for Site Recommendation* (CRWMS M&O 2000d). This assumption is conservative because it assumes that all baskets are staged in the basket staging racks prior to being transferred into pool storage. However, the ATS design allows for assemblies to be loaded directly into baskets positioned on a basket transfer cart and transferred to the storage pools without being staged. This option results in one less basket lift underwater.

This assumption is used to calculate basket event frequencies in Attachment VII. This assumption requires confirmation before the frequency and dose results associated with SFA events (Attachments V, VII and IX) can be qualified.

Input Status: Unqualified.

3.11 Crane maintenance will be performed once per year in the WHB.

Basis: A maintenance interval of one year is considered a minimal requirement for safety-related equipment procured, inspected, tested, and maintained in accordance with a nuclear quality assurance program.

This assumption is used to generate the probability of handling equipment drops onto a wasteform. It is postulated that, during scheduled maintenance of the overhead crane control system, a failure to follow written procedures could result in the control system being disabled. This assumption is used in Attachment VI and Attachment VII. This assumption does not require further confirmation because it has a minimal impact on the calculation results.

Input Status: N/A – Not Critical.

3.12 Waste handling operations at the MGR will continue for thirty (30) years.

Basis: 30-years is the nominal operational period required to accomodate the projected CSNF waste stream at the MGR. This assumption is based on the *1999 Design Basis Waste Input Report for Commercial Spent Nuclear Fuel* (CRWMS M&O 1999a).

This assumption is used in Attachment VII to calculate the average number of failed fuel SECs received per year. This assumption does not require further confirmation because it has a minimal impact on the calculation results.

Input Status: N/A – Not Critical.

3.13 Not Used.

3.14 Shipping cask (without impact limiters) handling operations at the MGR include: (1) one lift off a rail/truck and onto a cask transfer cart, (2) one lower into the Cask Preparation Pit, (3) one lift out of the Cask Preparation Pit, and (4) one lower into the Cask Unloading Pool.

Basis: This assumption is based on operational descriptions of the cask handling operations in the *Surface Design Description for Site Recommendation* (CRWMS M&O 2000d).

This assumption is used to calculate shipping cask event frequencies in Attachment VII. This assumption requires confirmation before the frequency results associated with shipping cask events (Attachment VII) can be qualified.

Input Status: Unqualified.

3.15 The MGR is designed to prevent a credible breach of a sealed shipping cask or WP containing commercial SNF.

Basis: The MGR preclosure safety strategy is to design the facility such that a breach of a sealed shipping cask, WP, or disposable canister is not credible, with consideration given to manufacturing flaws/defects and expected design basis events at the MGR (CRWMS M&O 1999g). This assumption is used in Attachment VII as the basis for not evaluating the event frequencies associated with sealed cask, canister and WP breaches. The breach of a cask and WP were considered as non-mechanistic events (Attachment VII, Events NM-01 and NM-02) and included in the Category 2 offsite dose assessment for completeness. This assumption requires further confirmation to verify that MGR design and operational controls are in place to ensure that these events are beyond design basis.

Input Status: Unqualified.

3.16 Not Used.

3.17 The preclosure breach of a CSNF shipping cask and "Early Failure" of a WP loaded with CSNF are deterministically assumed to occur.

Basis: This assumption was made in order to assess the dose consequences of these events. It is assumed that these events will be shown by analysis to be incredible based on facility design controls and design of the shipping casks and WPs. This assumption is consistent with the MGR preclosure safety strategy to contain radionuclides in the sealed shipping casks during receipt of waste and in the sealed WPs during the emplacement of WPs (CRWMS M&O 1998d).

Failure modes for early failure of a WP were evaluated in *Analysis of Mechanisms for Early Waste Package Failure* (CRWMS M&O 2000f). Although the term "early failure" has a postclosure connotation and refers to WP failures within their expected 1,000 year performance lifetime, this reference (CRWMS M&O 2000f) also provides insight to the potential mechanisms for failure in the preclosure period. The reference cites a WP defect probability of 1.5×10^{-5} to 3.0×10^{-5} per WP for improper weld material and 2.2×10^{-5} per WP for improper heat treatment. However, there is no indication that a pre-existing defect could potentially result in a through-wall breach of the WP during the preclosure period. The consequences of a WP early failure (Assumption 3.18) are analyzed primarily to demonstrate the low risk associated with an unfiltered, deterministic release of the radioactive gases contained in a WP with a bounding radiological source term.

This assumption is used in Attachment VII to determine event sequences for consequence analysis. This assumption does not require confirmation because these events, unmitigated, result in negligible offsite doses to the public.

Input Status: N/A – Not Critical.

3.18 The non-mechanistic consequence assessment of a shipping cask leak (Event NM-01) or early WP failure in the preclosure period (Event NM-02) assumes the following:

- All barriers of a shipping cask or WP (e.g., inner and outer shells) are breached.
- The breached cask contains 68-BWR assemblies and the breached WP contains 21-PWR assemblies, each with the maximum source term (Attachment VIII).
- 100% of the fuel rods in each assembly are breached.
  - Release of 30% of the radioactive gas inventory.
  - No particulate releases because it is assumed that the cask or WP leak is very small and that there is insufficient pressure to expel the particulate radionuclides.
- Unmitigated dispersion to the site boundary from the Carrier Bay (11,000 meters distance) for cask releases and from the subsurface exhaust shaft (8,000 meters distance) for WP releases, using the 99.5% maximum sector acute χ/Q.

Basis: These events are evaluated deterministically even though they are not expected to be credible events. These consequence parameters are consistent with conservative Category 2 dose calculation parameters. This assumption does not require confirmation because the offsite public doses associated with these events and the assumed parameters are negligible.

Input Status: N/A – Not Critical.

3.19 The maximum material-at-risk (MAR) for events evaluated in this calculation is as follows:

Individual SFA Events:	1 PWR or 1 BWR assembly
SFA Drops onto Another SFA:	2 PWR or 2 BWR assemblies
Individual Basket Events:	4 PWR or 8 BWR assemblies
Basket Drops onto Another Basket:	8 PWR or 16 BWR assemblies
Unsealed DC and WP Events:	21 PWR or 44 BWR assemblies
Shipping Cask Events:	24 PWR or 68 BWR assemblies

Basis: This assumption is conservative based because it assumes all events occur with the maximum potential fuel loading. SFA basket and DC/WP capacities are based on the SR design concept for fuel handling and storage (CRWMS M&O 2000d). The maximum shipping cask capacities are based on *1999 Design Basis Waste Input Report for Commercial Spent Nuclear Fuel* (CRWMS M&O 1999a).

This assumption is used in Attachments VII, IX and X. This assumption requires confirmation before the frequency and dose results can be qualified.

Input Status: Unqualified.

3.20 The cladding damage fraction (DF), cladding release fraction (CR), and local deposition factor (DEP) for all events evaluated in this calculation are equal to 1.0.

Basis: Each of these fractions is conservatively bounding. A cladding damage fraction of 1.0 implies that 100% of the fuel rods from the assemblies involved in a given event (i.e., 100% of the MAR) are breached. A cladding release fraction of 1.0 implies that 100% of the MAR in the fuel-cladding gap escapes to the environment (i.e., no credit for retention in the cladding). A local deposition factor of 1.0 implies that none of the radioactive material involved in an event will be retained or deposited in the local area.

This assumption is used to calculate effective release fractions in Attachments V, IX and X. This assumption does not require further confirmation because it is a bounding assumption which maximizes the calculation results.

Input Status: N/A – Not Critical.

3.21 For SNF events occurring in a pool (e.g., drops, collisions), radioactive particulates and volatiles (Cs nuclides) are completely contained by the pool water (i.e., ARF=0) and only the noble gases (i.e., H-3, Kr-85 and I-129) are released (i.e., ARF=0.3).

Basis: Pool water is a very effective barrier and retains any radioactive particulates released during an event. The "gas only" release assumption is consistent with NRC Regulatory Guide 1.25, *Assumptions Used for Evaluating the Potential Radiological Consequences of a Fuel Handling Accident in the Fuel Handling and Storage Facility for Boiling and Pressurized Water Reactors*.

This assumption is used in Attachments V, IX and X to calculate the effective release fractions in water. This assumption does not require confirmation because the technical information is from NRC guidance.

Input Status: N/A – NRC Guidance/Codes & Standards.

3.22 Nuclides of Cesium (Cs-134, Cs-135 and Cs-137) exist in the volatile liquid or particulate state prior to being exhausted through the HEPA filters and, therefore, are retained by the HEPA filters with the same minimum efficiency as other particulates (99%, see Assumption 3.23).

Basis: Elemental Cesium has a melting point of 28° Celsius and a boiling temperature of 678° Celsius. At temperatures above 28° Celsius, Cesium isotopes can potentially exist in the liquid or vapor phase. Although the vapor phase would not be retained by HEPA filters, the liquid phase Cesium compounds would likely be filtered similar to particulates. Vapor-phase Cesium nuclides are extremely reactive and have a strong affinity to combine with other elements (such as Iodine) in either the fuel matrix or the fuel-cladding gap. This recombination process may also occur when the vapor-phase Cs comes in direct contact with surfaces during dispersion of the plume between the release point and the HEPA filters. It is reasonable to assume that below 28° Celsius all of the Cesium released from CSNF during a design basis event will be condensed into a particulate state prior to reaching the HEPA filters. Although this assumption may not be conservative for WHB environment temperatures above 28° Celsius, the HEPA filter removal efficiency for Cesium at temperatures below 28° Celsius is very conservative (see discussion of HEPA

filter mitigation factor conservatism in Section 6.3) and the probability that vapor-phase Cesium nuclides will reach the HEPA filters is very low.

This assumption is used in Attachments V, IX and X to calculate the effective release fractions in air. This assumption requires confirmation before the dose results for events occurring in dry handling areas of the WHB can be qualified.

Input Status: Unqualified.

3.23 A single-stage HEPA filter will retain at least 99% (i.e., mitigation factor of .01) of all non-gaseous/non-volatile (e.g., particulate) radionuclide releases that are exhausted through the HEPA filters by the WHB HVAC system.

Basis: The NRC considers a minimum 99% particulate removal efficiency to be warranted for a HEPA filtration system that is designed, maintained and tested in accordance with Regulatory Guide 1.140, *Design, Testing, and Maintenance Criteria for Normal Ventilation Exhaust System Air Filtration and Adsorption Units of Light Water Cooled Nuclear Power Plants*. The same minimum particulate removal efficiency is also cited in Regulatory Guide 1.52 for use in performing accident dose evaluations. The HEPA filters at the MGR are assumed to be designed and maintained, at a minimum, in accordance with Regulatory Guides 1.140 and 1.52.

This assumption is used in Attachments V, IX and X to calculate the mitigated radiological releases from the WHB. This assumption does not require confirmation because the technical information is from NRC guidance.

Input Status: N/A - NRC Guidance/Codes & Standards.

3.24 For Category 1 dose assessment, all respirable fractions are equal to 1.0, i.e., no credit is taken for the respirable fractions reported in *Commercial SNF Accident Release Fractions* (CRWMS M&O 1999d).

Basis: The referenced document (CRWMS M&O 1999d) recommended respirable fractions of 0.005 for nuclides of Strontium, Rubidium, and all other fuel fines. However, the subject document was focused on determining the release fraction for calculating inhalation doses. Since the ingestion pathway is included in the calculation of public doses due to Category 1 events, and particle sizes greater than 10 micron contribute equally to the ingestion dose, no credit was taken for the respirable portion of the Category 1 event source terms.

This assumption is used in Attachment IX to calculate the effective release fractions in air, which are used to generate the Category 1 event source terms that are input into GENII-S. This assumption does not require further confirmation because it is a bounding assumption which maximizes the calculation results.

Input Status: N/A – Not Critical.

3.25 All radiological releases due to Category 1 and Category 2 events occur at the ground level.

Basis: Ground-level releases are generally expected to result in conservative doses at 100-m, 8-km and 11-km distances compared with an elevated release. Although an exhaust stack will be part of the MGR design and elevated releases are expected, this calculation assumes ground releases for conservatism. Furthermore, the site-specific atmospheric dispersion factors used in this calculation are based on a ground level release (CRWMS M&O 1999c). Note: Category 1 releases from the subsurface are also expected to be exhausted through elevated stacks on top of Yucca Mountain.

This assumption is used in Attachment V to calculate non-involved worker doses at 100-m and in Attachments IV and X to calculate Category 1 and Category 2 doses to the public at the site boundary. This assumption does not require further confirmation because it is a conservative assumption and has a minimal impact on the calculation results.

Input Status: N/A – Not Critical.

3.26 The average transfer time for SFA and SFA basket transfer operations is equal to 0.5 hours.

Basis: An average transfer time of 0.5 hours per operation is judged to be a conservative estimate of the operational time associated with each movement of spent fuel.

The transfer time is multiplied by the "all modes" failure rate of 6.0×10^{-6} per hour (IEEE 1984) to calculate the probability of a spurious movement or equipment failure that results in a collision involving SFAs or SFA baskets. This assumption is also used to calculate the probability of an uncontrolled descent of the Incline Transfer Cart during movement up the transfer canal.

This assumption is used in Attachment VII to calculate event frequencies for SFA and SFA basket collisions, and the uncontrolled descent of an Incline Transfer Cart. This assumption does not require confirmation because the affected events (Attachment VII, Events 1-02, 1-06, 1-09 and 1-11) are currently classified as Category 1, the highest frequency category. Furthermore, the event frequencies are relatively insensitive (compared to the "all modes" failure rate) to the transfer time and a reasonable (e.g., ± 1-hr) increase or decrease would not change the frequency classification.

Input Status: N/A – Not Critical.

3.27 The preclosure period (from start of repository operations to permanent closure) is 100 years.

Basis: This assumption is based on the typical preclosure period cited in previous DBE analyses (CRWMS M&O 1999g). This assumption is used in Section 2.1 to define the DBE frequency categories and in Attachment VII to calculate the frequency category for

each event sequence. This assumption is based on unqualified information and must be verified before the frequency results can be considered qualified.

Input Status: Unqualified.

3.28 The overhead crane systems in the Waste Handling Building have at least two of every active component necessary to support the load, prevent a spurious movement, or detect an operator error that could result in a physical impact to vulnerable SNF (i.e., SNF not contained in a sealed cask, canister or WP).

Basis: This assumption of redundance in the crane system is typical of heavy-lift bridge cranes at nuclear power plants and provides the basis for determining the probability of a yoke drop onto SNF.

This assumption is used in Attachment VI to develop the fault tree for a yoke drop and in Attachment VII to calculate event frequencies for yoke drops onto a SFA, SFA basket, or unsealed DC. This assumption does not require further confirmation because it has a minimal impact on the calculation results.

Input Status: N/A – Not Critical.

3.29 A beta factor of 0.1 is assumed to represent common-mode failures of redundant systems or components.

Basis: The beta factor model provides a conservative approximation of common cause failure rates for a system of redundant components (EPRI 1988). A beta factor of 0.1 is a conservative value for screening purposes. This assumption is used in Attachment VI to develop the fault tree for a yoke drop onto SNF. This assumption does not require confirmation because the technical information is from NRC guidance.

Input Status: N/A - NRC Guidance/Codes & Standards.

3.30 The exposure time that a lifting yoke is suspended above SNF during normal waste handling operations is less than 1 minute per lift.

Basis: A typical no-load hook speed (vertical motion) for heavy-lift bridge cranes is 16 feet/minute (CRWMS M&O 1997) and the typical travel distance from the yoke hook height to the top of an assembly, assembly basket, or disposal container is expected to be less than 16 feet during normal waste handling operations. Therefore, it is reasonable to assume that the yoke will be suspended above SNF for less than 1 minute per lift.

A 2x increase in the exposure time results in a 1.5x increase in the top event probability of a yoke drop (Attachment VI). However, a twofold increase does not change the frequency category (Category 2) of this DBE. Consequently, this assumption has a minimal impact on the calculation results and does not require further confirmation.

Input Status: N/A – Not Critical.

3.31 External air submersion doses are dominated by the contributions from two radionuclides, H-3 and Kr-85, therefore dose contributions from other radionuclides may be ignored.

Basis: This assumption is based on analyst experience in performing dose calculations. H-3 (tritium) and Kr-85 are the only gases present in sufficient quantities, in the source terms analyzed (see Attachment VIII), to contribute to the air submersion dose. This assumption is used in Attachments V and X to calculate the air submersion DDE for non-involved workers and the public, respectively.

Unqualified hand calculations have been performed which compare the DDE dose from all radionuclides present in the source term versus the DDE dose due only to H-3 and Kr-85 and were found to result in less than a factor of 10 increase. In addition, the DDE dose for the bounding Category 2 event (Attachment X, Event 2-11) is nearly two orders of magnitude lower than the CEDE dose for the same event, therefore, an order of magnitude increase in the DDE would have a minimal effect on the TEDE dose result (recall from Section 2.2 that TEDE is equal to CEDE plus DDE). Consequently, this assumption does not require further confirmation.

Input Status: Not Critical.

4. USE OF COMPUTER SOFTWARE AND MODELS

This calculation utilized the computer code GENII-S, version 1.4.8.5 (CRWMS M&O 1998c). GENII-S is a computer program used to calculate statistical and deterministic values of radiation doses to humans from exposure to radionuclides in the environment.

The use of GENII-S to perform the Category 1 dose assessment is described in Section 4.1. Software routines and macros used in this calculation are described in Section 4.2. No models were developed for this calculation.

4.1 SOFTWARE

GENII-S is a qualified software code (CSCI: 30034 V1.4.8.5) (CRWMS M&O 1998c) consisting of executable programs and auxiliary files, all of which are appropriate for this application and were used within the range of validation as described in the software qualification report (CRWMS M&O 1998c). The copy of GENII-S software used for this calculation was obtained from Configuration Management and run on a Gateway 2000 PC (CRWMS M&O tag # 117305).

GENII-S is a successor to the Pacific Northwest Laboratories code, GENII. GENII, which is available from the Radiation Safety Information Computational Center (RSICC) as code CCC_601, was developed to incorporate the internal dosimetry models recommended by the ICRP, Publications 26 (ICRP 1977) and 30 (ICRP 1979), into the environmental pathway analysis models used at the Hanford Reservation. GENII is a coupled system of seven programs and the associated data libraries that comprise the Hanford Dosimetry System (Generation II) to estimate potential radiation doses to individuals or populations from both routine and accidental releases. The programs analyze environmental contamination resulting from both far-field and

near-field scenarios and calculated radiation doses to humans. GENII can be used in prospective dose calculations for purposes such as siting facilities, environmental impact statements, and safety analysis reports. GENII-S is the GENII code implemented in a software shell, Sensitivity and UNcertainty analysis Shell (SUNS). GENII-S has the same physical models as GENII with additional capability to perform Monte Carlo simulation. This added feature is a useful tool for identifying important model input parameters and evaluation uncertainty of model output.

4.2 SOFTWARE ROUTINES

4.2.1 Documentation of Information Required by AP-SI.1Q

Software routines and macros, as defined by AP-SI.1Q, are used in this analysis – specifically, an Excel workbook. The procedure requires documentation of the following information regarding workbooks and macros:

A listing of the version and any subsequent changes to the software:

- The workbooks used in this calculation have no specific version; they are explicitly coupled with this calculation and its documentation. No changes can be made to the workbook without a revision of this calculation document, or the production of a separate calculation that documents the changes.

The version identification of the application the routine or macro was developed in:

- The workbooks used in this calculation were developed in Microsoft Excel 97 SR-2 under the Windows 95 operating system, on a Gateway 2000 PC (CRWMS M&O tag # 117305).

Documentation that the workbook and macro provide correct results for a specified range of input parameters:

- The checking process provides verification that the results documented in Attachments IV, V, VI, VII, VIII, IX, X and XI are correct for the input data contained therein.

The installation and checkout steps performed upon first use of the software routine or macro on a new platform, operating system, or new user's location:

- The workbooks used herein have been developed to function under Excel 97 on a PC platform with the Windows 95 operating system. Execution of the workbooks under a different version of Excel, on a different computing platform, and/or with a different operating system may impact the veracity of their results.

4.2.2 Workbook and Macro Information

This calculation uses Excel workbooks to generate event frequencies (Attachment VII) and radiological source terms (Attachment VIII), calculate Category 1 DBE releases (Attachment IX), and calculate non-involved worker doses (Attachment V) and Category 2 public dose consequences (Attachment X). The Excel workbooks and the worksheets contained in each of these attachments are discussed below:

Attachment V – Non-Involved Worker Dose Calculations – Calculates annual 100-m air submersion dose consequences resulting from Category 1 DBEs, including normal releases.

- ***Events-Frequencies***: Contains a listing of the Category 1 events, event numbers, locations and sequence frequencies from the frequency calculations in Attachment VII. This worksheet also contains two MAR columns, one for the maximum number of PWR SFAs and the other for the maximum number of BWR SFAs that are at risk for each given event.

- ***Normal Releases***: Includes the normal (i.e., routine, chronic) annual releases (Ci/yr) expected from the surface and subsurface facilities. The surface release is based on Input Transmittal RSO-SUF-99389.T.a (CRWMS M&O 2000a) and the subsurface release is based on Input Transmittal RSO-SSR-99412.T (CRWMS M&O 2000b). This worksheet contains the dose coefficients for air submersion from Eckerman and Ryman (1993) for the nuclides involved in the normal surface and subsurface releases. This worksheet calculates the submersion DDE dose to non-involved workers at 100-m due to normal operational releases.

- ***Avg Dose***: Contains the average PWR and BWR source terms per fuel assembly (Curies/FA), and the average PWR/BWR inhalation dose (rem/FA) to each organ, by nuclide. This worksheet also contains the average PWR and BWR submersion dose (rem-m^3/FA-s) due to H-3 and Kr-85. Inhalation and submersion doses were calculated in Attachment VIII using the method described in Section 2.2. Average source terms per fuel assembly for PWR and BWR fuel are from *PWR Source Term Generation and Evaluation* (CRWMS M&O 1999h) and *BWR Source Term Generation and Evaluation* (CRWMS M&O 1999b), respectively.

- ***Max Dose***: Contains the maximum PWR and BWR source terms per fuel assembly (Curies/FA), and the maximum PWR/BWR inhalation dose (rem/FA) to each organ, by nuclide. This worksheet also contains the maximum PWR and BWR submersion dose (rem-m^3/FA-s) due to H-3 and Kr-85. Inhalation and submersion doses were calculated in Attachment VIII using the method described in Section 2.2. Maximum source terms per fuel assembly for PWR and BWR fuel are from *PWR Source Term Generation and Evaluation* (CRWMS M&O 1999h) and *BWR Source Term Generation and Evaluation* (CRWMS M&O 1999b), respectively.

- ***Crud***: This worksheet calculates the crud source terms and inhalation organ doses (rem/FA) due to Co-60 and Fe-55 for the event selected in the ***Input*** worksheet. Input fields include the assembly surface area, Co-60 and Fe-55 half lives, conversion factors for Becquerels (Bq) per microcurie (μCi) and Rem per Sievert (Sv), inhalation dose conversion factors (units of Sv/Bq) for Co-60 and Fe-55, and whether Fe-55 is considered in the calculation (yes or no). Calculated fields include the crud decay time (years), surface activity (μCi/cm^2), crud source (Ci/FA), and crud inhalation dose (rem/FA) to each organ. The crud decay time is calculated using an IF function as either 5 or 25 years, depending on whether a maximum or average fuel type is selected in the **Inputs** worksheet.

- ***Groupings***: This worksheet groups each of the source term nuclides into one of four categories in order to simplify the organ dose calculations. The four groups are: fuel

particulates (p), noble gases (g), cesium (cs), and strontium (sr). The columns displayed include the group letter, nuclide, and organ doses for Gonad, Breast, Lung, Bone Marrow (identified as R.Marrow in the worksheet), Bone Surface, Thyroid, Remainder, and Whole Body. The organ dose fields (Gonad, Breast, etc.) use a VLOOKUP function to compare the nuclide field and return the inhalation dose (rem/FA) from the appropriate dose worksheet (**Avg Dose** or **Max Dose**), depending on the fuel type selected.

- ***Grouped Sources*:** This worksheet sums the inhalation doses (rem/FA) from the ***Groupings*** worksheet for each of the group letters (p, g, cs, sr) and also sums the crud (c) inhalation doses (rem/FA) from the ***Crud*** worksheet.

- ***RFs*:** Contains the release fractions (RFs) for each group of radionuclides. Groups include particulates, crud, Rubidium (Ru), Strontium (Sr), Cesium (Cs), I-129, Kr-85, and H-3. The groupings and CSNF release fractions for drops in a dry environment are based on results in *Commercial SNF Accident Release Fractions* (CRWMS M&O 1999d). Release fractions for pool events involving CSNF are also provided in this worksheet. The cladding damage fraction, local deposition, and cladding release fraction are shown in the worksheet for completeness, but conservatively set to unity to calculate the effective release fraction (Assumption 3.20).

  Note: No Rubidium isotopes are included in the source terms used.

- ***χ-Q Values*:** Contains the maximum sector chronic χ/Q values at distances of 8,000 meters and 11,000 meters, interpolated from data in *Calculations of Acute and Chronic "Chi/Q" Dispersion Estimates for a Surface Release* (CRWMS M&O 1999c). The calculation of these interpolations is performed in Attachment IX, worksheet ***Cat. 1 χ-Q Values***.

- ***Submersion*:** Selects the appropriate submersion dose rate (rem-m^3/FA-s) from the ***Avg Dose*** or ***Max Dose*** worksheets and calculates the 100-m non-involved worker submersion dose (rem) to each organ for each Category 1 event, per the method in Section 2.2. The offsite submersion dose (rem) attributed to a specific event is equal to the submersion dose rate (rem-m^3/FA-s) multiplied by the number of fuel assemblies (FA) involved in the event, release fraction, mitigation factor, and χ/Q (s/m^3).

- ***Gonad*:** This worksheet calculates the 100-m non-involved worker inhalation dose (rem) to the gonad. This worksheet collects the appropriate inhalation dose for each nuclide grouping from the Grouped Sources worksheet and the number of fuel assemblies involved, release fraction, mitigation factor, breathing rate, and χ/Q values from the ***Inputs*** worksheet, based on the user-selected inputs. The inhalation dose to the gonad for each nuclide group is equal to the product of all these inputs (i.e., Source Term · Number of FAs · Release Fraction · Mitigation Factor x Breathing Rate · χ/Q). The total inhalation dose (rem) to the gonad is calculated as the sum of each nuclide group total.

- ***Breast, Lung, Marrow, Bone Surface, Thyroid, Remainder,* and *Whole Body* Worksheets:** Each of these worksheets is identical to the ***Gonad*** worksheet, except that the inhalation dose (rem/FA) from the ***Grouped Sources*** worksheet is selected based on that particular organ.

- **Annual Dose:** This worksheet compiles the HEPA-mitigated annual doses (rem/yr) to a non-involved worker at 100-m for each Category 1 event, including normal operational releases. This worksheet also calculates the total TEDE, CDE_{max}+DDE, eye and skin doses for all Category 1 events.

- ***Input*:** Contains the input parameters for calculating 100-m non-involved worker dose consequences due to Category 1 releases. Input fields include the fuel type (Average PWR held constant), event description, whether or not the event occurs in a pool, HEPA mitigation (i.e., with or without HEPA filtration), χ/Q type (max sector chronic held constant), χ/Q distance (100-m held constant), breathing rate (m^3/s), and whether a ground release is assumed (yes or no). Calculated fields include the event number, location, event frequency, number of damaged assemblies involved, mitigation factor, and χ/Q value. The calculated fields are either VLOOKUP functions from the range "Event_desc" or "IF" functions based on the input variables selected.

- **Summary:** This worksheet contains a per event summary of each organ inhalation dose (rem/event) and organ submersion dose (rem/event), and calculates the DDE, CDE, CEDE, TEDE, eye dose, and skin dose in accordance with Section 2.2. The TEDE, CDE_{max}+DDE, eye dose, and skin doses (rem/event) are multiplied by the event frequency (events/yr) to determine the annual doses to a non-involved worker at 100-m.

- **Test Cases:** This worksheet includes validation test cases for unique formulas used in this Attachment. Included are the applicable cells for which the formulas apply, test input values, computer-generated output, and output generated by hand calculation for verification.

Attachment VII – Frequency Calculations. Calculates event sequence frequencies and determines whether an event sequence is Category 1, Category 2, or beyond design basis.

- **Input Data:** Contains the input data and assumptions necessary to calculate event sequence frequencies.

- **Throughput:** Includes the maximum annual throughput assumptions for PWR/BWR assemblies, PWR/BWR baskets, shipping casks, and failed fuel contained in single element canisters (SECs).

- **Failure Rates:** Contains the structures, systems and components (SSCs) that are postulated to fail during a DBE, and their assumed failure rates.

- **DBEs:** This worksheet uses input data from the previous three worksheets and calculates the event sequence frequencies and associated DBE category. Each of the columns in this worksheet are described in further detail below:

  (A) **List of Operations** – Includes a list of the operations (lifts and movements) involved in each area of the WHB where commercial SNF is handled. Included are the

Assembly Transfer System (ATS) operations, DC handling operations, and cask handling operations.

(B) **Event** – Identifies the event postulated to occur as a result of equipment failure or human error during an operation.

(C) **Event #** - A unique identifier for each event sequence. Category 1 events are identified as Event # 1-xx; Category 2 events are 2-xx; and beyond design basis events (BDBEs) are identified as BDBE-xx, where xx is a sequential number beginning with 01.

(D) **Occurs in Pool?** – This is a yes (Y) or no (N) field and identifies whether the postulated event occurs in a pool or, alternatively, in a hot cell.

(E) **Conditional Probability** – The fraction of an event probability that results in a particular outcome. For example, a SFA drop while positioned above a spent fuel basket will result in one of two outcomes: a drop onto an empty basket or a drop onto a partially loaded basket. Since the consequences of each drop are different, the conditional probability divides the event into two event sequences. A conditional probability other than 1.0 is calculated for events 1-03, 1-04, 2-04, 2-05, 2-06, and 2-07. The conditional probabilities for these events are based on data from worksheets ***Input Data*** and ***Throughput***.

(F) **Material-At-Risk (# SFAs)** – Contains the maximum number of BWR and PWR assemblies that could potentially be involved in a given event.

(G) **SSC Failure** – Identifies the SSC that is postulated to fail and initiate the event sequence.

(H) **Failure Rate** – The failure rate assumed for the postulated SSC failure.

(I) **Units** – The dimensional unit of the failure rate, e.g., drops/lift or failures/movement.

(J) **Maximum # Lifts or Operations per Year** – The maximum number of lifts or operations assumed; linked to the **Input Data** and/or **Throughput** worksheets.

(K) **Event Frequency (per year)** – Calculates the product of Conditional Probability, Failure Rate and Maximum # Lifts or Operations per Year.

(L) **HVAC Available?** – A yes (Y) or no (N) field to differentiate the event into two separate sequences - both with and without the HVAC system available to mitigate any potential releases.

(M) **HVAC Availability** – The probability that the primary HVAC system is available or unavailable to mitigate potential releases. This number is based on the probability of an unfiltered release due to HVAC failure (1.72×10^{-7}) calculated in *Reliability Assessment of Waste Handling Building HVAC System* (CRWMS M&O 1999i).

(N) **Sequence Frequency (per year)** – The final event sequence frequency which takes into account whether the HVAC system is available or unavailable. This field calculates the product of **Event Frequency** and **HVAC Availability**.

(O) **Event Sequence Category** – Calculates the DBE category associated with the Sequence Frequency based on an IF function; "Category 1" if greater than or equal to 10^{-2} per year, "Category 2" if less than 10^{-2} per year but greater than or equal to 10^{-6} per year, and "BDBE" if less than 10^{-6} per year.

- **Test Cases:** This worksheet includes validation test cases for unique formulas used in this Attachment. Included are the applicable cells for which the formulas apply, test input values, computer-generated output, and output generated by hand calculation for verification.

Attachment VIII – SR Source Term Calculations. Calculates organ inhalation doses (rem/FA) by nuclide and serves as input to Attachments V, IX and X.

- ***INHAL. DCFs*:** Contains inhalation DCFs from Federal Guidance Report No. 11 (Eckerman et al. 1988).

- ***Avg_PWR Inv*:** Average PWR assembly inventories (Ci/FA) from *PWR Source Term Generation and Evaluation* (CRWMS M&O 1999h).

- ***Max_PWR Inv*:** Maximum PWR assembly inventories (Ci/FA) from *PWR Source Term Generation and Evaluation* (CRWMS M&O 1999h).

- ***Avg_BWR Inv*:** Average BWR assembly inventories (Ci/FA) from *BWR Source Term Generation and Evaluation* (CRWMS M&O 1999b).

- ***Max_BWR Inv*:** Maximum BWR assembly inventories (Ci/FA) from *BWR Source Term Generation and Evaluation* (CRWMS M&O 1999b).

- ***Avg_PWR Dose*:** Calculates the average PWR inhalation dose (rem/FA), by nuclide, for each organ. The average PWR inhalation dose is obtained by multiplying the nuclide activity (Ci/FA) by the organ DCF (Sv/Bq) and by a conversion factor of 3.7×10^{12} rem-Bq/Ci-Sv. The nuclide activity and DCF values are obtained by VLOOKUP function from worksheets **Avg_PWR Inv** and **INHAL. DCFs**, respectively.

- ***Max_PWR Dose*:** Calculates the maximum PWR inhalation dose (rem/FA), by nuclide, for each organ. The average PWR inhalation dose is obtained by multiplying the nuclide activity (Ci/FA) by the organ DCF (Sv/Bq) and by a conversion factor of 3.7×10^{12} rem-Bq/Ci-Sv. The nuclide activity and DCF values are obtained by VLOOKUP function from worksheets **Max_PWR Inv** and **INHAL. DCFs**, respectively.

- ***Avg_BWR Dose*:** Calculates the average BWR inhalation dose (rem/FA), by nuclide, for each organ. The average BWR inhalation dose is obtained by multiplying the nuclide

activity (Ci/FA) by the organ DCF (Sv/Bq) and by a conversion factor of $3.7x10^{12}$ rem-Bq/Ci-Sv. The nuclide activity and DCF values are obtained by VLOOKUP function from worksheets **Avg_BWR Inv** and **INHAL. DCFs**, respectively.

- ***Max_BWR Dose*:** Calculates the maximum BWR inhalation dose (rem/FA), by nuclide, for each organ. The average BWR inhalation dose is obtained by multiplying the nuclide activity (Ci/FA) by the organ DCF (Sv/Bq) and by a conversion factor of $3.7x10^{12}$ rem-Bq/Ci-Sv. The nuclide activity and DCF values are obtained by VLOOKUP function from worksheets **Max_BWR Inv** and **INHAL. DCFs**, respectively.

- ***Submersion Dose*:** Calculates the external submersion dose rate (rem-m^3/FA-s) due to Tritium (H-3) and Krypton-85 (Kr-85), by organ, for each of the four fuel types. External dose coefficients for air submersion are from Eckerman and Ryman (1993). Source terms (Ci/FA) used to calculate submersion doses are obtained by VLOOKUP function from each of the inventory worksheets (e.g., **Avg_PWR Inv** for average PWR fuel). See Equation (7) for the formula used to calculate submersion dose.

- **Test Cases:** This worksheet includes validation test cases for unique formulas used in this Attachment. Included are the applicable cells for which the formulas apply, test input values, computer-generated output, and output generated by hand calculation for verification.

Attachment IX – Category 1 Event Release Calculations. Calculates the annual source term releases, by nuclide, for Category 1 events.

- ***Events-Frequencies*:** Contains a static (i.e., cut and paste) listing of the Category 1 events, event numbers and sequence frequencies from the frequency calculations in Attachment VII. This worksheet also contains two MAR columns, one for the maximum number of PWR SFAs and the other for the maximum number of BWR SFAs that are at risk for each given event.

- ***Avg Source*:** Contains the average PWR and BWR source terms per fuel assembly (Curies/FA) from *PWR Source Term Generation and Evaluation* (CRWMS M&O 1999h) and *BWR Source Term Generation and Evaluation* (CRWMS M&O 1999b), respectively.

- ***Crud Source*:** This worksheet calculates the crud source term released for the event selected in the ***Input*** worksheet. Input fields include the decay time, assembly surface area, Co-60 and Fe-55 half lives, conversion factors for Becquerels (Bq) per microcurie (μCi) and Rem per Sievert (Sv), and whether Fe-55 is considered in the calculation (yes or no). Calculated fields include the crud decay time (years), surface activity (μCi/cm2) and crud source (Ci/FA). The crud decay time is calculated using an IF function as either 5 or 25 years, depending on whether a maximum or average fuel type is selected in the **Inputs** worksheet.

- ***χ-Q Values*:** Contains the chronic χ/Q values interpolated from *Calculations of Acute and Chronic "Chi/Q" Dispersion Estimates for a Surface Release* (CRWMS M&O 1999c) at distances of 8,000 meters and 11,000 meters.

- ***RFs*:** Contains the release fractions (RFs) for each group of radionuclides. Groups include particulates, crud, Rubidium (Ru), Strontium (Sr), Cesium (Cs), I-129, Kr-85, and H-3. The groupings and CSNF release fractions for drops in a dry environment are based on results in *Commercial SNF Accident Release Fractions* (CRWMS M&O 1999d), with the exception of the respirable fraction. The respirable fractions were assumed equal to zero in order to conservatively calculate the ingestion dose (Assumption 3.24). Release fractions for pool events involving CSNF are also provided in this worksheet. The cladding damage fraction, local deposition, and cladding release fraction are shown in the worksheet for completeness, but conservatively set to unity to calculate the effective release fraction (Assumption 3.20). Note: No Rubidium isotopes are included in the source terms used.

- ***Normal Releases:*** Includes the normal (i.e., routine, chronic) annual releases (Ci/yr) expected from the surface and subsurface facilities. The surface release is based on Input Transmittal RSO-SUF-99389.T.a (CRWMS M&O 2000a) and the subsurface release is based on Input Transmittal RSO-SSR-99412.T (CRWMS M&O 2000b).

- ***Inputs*:** Contains the input parameters for the Category 1 release calculations. Input fields include the fuel type (e.g., average PWR or average BWR fuel), event number, whether or not the event occurs in a pool, HEPA mitigation (i.e., with or without HEPA filtration), χ/Q type (max sector chronic held constant), χ/Q distance, breathing rate (m^3/s), and whether a ground release is assumed (yes or no). Calculated fields include the event description, location, frequency, number of damaged assemblies involved, HEPA filter release fraction, and χ/Q value. The calculated fields are either VLOOKUP functions from the range "Event_desc" or "IF" functions based on the input variables selected.

- ***Cat. 1 DBE Release*:** This worksheet retrieves the correct source term for each nuclide (via VLOOKUP function) based on the fuel type selected in the ***Input*** worksheet and calculates the annual Curie release (Ci/yr) for each nuclide. The event frequency (events/year) and number of fuel assemblies involved are taken from the ***Input*** worksheet and the proper release fraction is selected from the ***RFs*** worksheet. The Curies Released (Ci/event) field is the calculated product of Source Term, # of FAs and Release Fraction. The Annual Cat. 1 DBE Release (Ci/yr) field is the calculated product of the Curies Released and Event Frequency fields.

- ***Total Cat. 1 DBE Release*:** Contains the Curies released per year, for each individual Category 1 event. The annualized release values (Ci/yr) are cut and pasted from the results of the ***Cat. 1 DBE Release*** worksheet for each of the 14 Category 1 events (Events 1-01 through 1-14). The Total Release Per Nuclide field calculates the total release per nuclide (Ci/yr) by summing the annual releases for each of the 14 events. These total nuclide values were used as input to the GENII-S code to calculate the "all pathways" TEDE dose.

- **Test Cases:** This worksheet includes validation test cases for unique formulas used in this Attachment. Included are the applicable cells for which the formulas apply, test input values, computer-generated output, and output generated by hand calculation for verification.

Attachment X – Category 2 DBE Dose Calculations – Calculates the offsite dose consequences to the public resulting from Category 2 DBEs.

- ***Events-Frequencies***: Contains a static (i.e., cut and paste) listing of the Category 2 events, event numbers and sequence frequencies from the frequency calculations in Attachment VII. This worksheet also contains two MAR columns, one for the maximum number of PWR SFAs and the other for the maximum number of BWR SFAs that are at risk for each given event.

- ***Avg Dose***: Contains the average PWR and BWR source terms per fuel assembly (Curies/FA), and the average PWR/BWR inhalation dose (rem/FA) to each organ, by nuclide. This worksheet also contains the average PWR and BWR submersion dose (rem-m^3/FA-s) due to H-3 and Kr-85. Inhalation and submersion doses were calculated in Attachment VIII using the method described in Section 2.2. Average source terms per fuel assembly for PWR and BWR fuel are from *PWR Source Term Generation and Evaluation* (CRWMS M&O 1999h) and *BWR Source Term Generation and Evaluation* (CRWMS M&O 1999b), respectively.

- ***Max Dose***: Contains the maximum PWR and BWR source terms per fuel assembly (Curies/FA), and the maximum PWR/BWR inhalation dose (rem/FA) to each organ, by nuclide. This worksheet also contains the maximum PWR and BWR submersion dose (rem-m^3/FA-s) due to H-3 and Kr-85. Inhalation and submersion doses were calculated in Attachment VIII using the method described in Section 2.2. Maximum source terms per fuel assembly for PWR and BWR fuel are from *PWR Source Term Generation and Evaluation* (CRWMS M&O 1999h) and *BWR Source Term Generation and Evaluation* (CRWMS M&O 1999b), respectively.

- ***Crud***: This worksheet calculates the crud source terms and inhalation organ doses (rem/FA) due to Co-60 and Fe-55 for the event selected in the ***Input*** worksheet. Input fields include the assembly surface area, Co-60 and Fe-55 half lives, conversion factors for Becquerels (Bq) per microcurie (μCi) and Rem per Sievert (Sv), inhalation dose conversion factors (units of Sv/Bq) for Co-60 and Fe-55, and whether Fe-55 is considered in the calculation (yes or no). Calculated fields include the crud decay time (years), surface activity (μCi/cm^2), crud source (Ci/FA), and crud inhalation dose (rem/FA) to each organ. The crud decay time is calculated using an IF function as either 5 or 25 years, depending on whether a maximum or average fuel type is selected in the **Inputs** worksheet.

- ***Groupings***: This worksheet groups each of the inhalation nuclides into one of four categories in order to simplify the organ dose calculations. The four groups are: fuel particulates (p), noble gases (g), cesium (cs), and strontium (sr). The columns displayed include the group letter, nuclide, and organ doses for Gonad, Breast, Lung, Bone Marrow, Bone Surface, Thyroid, Remainder, and Whole Body. The organ dose fields (Gonad, Breast, etc.) use a VLOOKUP function to compare the nuclide field and return the inhalation dose (rem/FA) from the appropriate dose spreadsheet (**Avg Dose** or **Max Dose**), depending on the fuel type selected.

- ***Grouped Sources***: This worksheet sums the inhalation doses (rem/FA) from the ***Groupings*** worksheet for each of the group letters (p, g, cs, sr) and also displays the crud (c) inhalation dose (rem/FA) from the ***Crud*** worksheet.

- ***RFs***: Contains the release fractions (RFs) for each group of radionuclides. Groups include particulates, crud, Rubidium (Ru), Strontium (Sr), Cesium (Cs), I-129, Kr-85, and H-3. The groupings and CSNF release fractions for drops in a dry environment are based on results in *Commercial SNF Accident Release Fractions* (CRWMS M&O 1999d). Release fractions for pool events involving CSNF are also provided in this worksheet. The cladding damage fraction, local deposition, and cladding release fraction are shown in the worksheet for completeness, but conservatively set to unity to calculate the effective release fraction (Assumption 3.20).

  Note: No Rubidium isotopes are included in the source terms used.

- ***χ-Q Values***: Contains the maximum sector acute χ/Q values, for distances of 8,000 meters and 11,000 meters, interpolated from data in *Calculations of Acute and Chronic "Chi/Q" Dispersion Estimates for a Surface Release* (CRWMS M&O 1999c).

- ***Submersion***: Selects the appropriate submersion dose rate (rem-m^3/FA-s) from the ***Avg Dose*** or ***Max Dose*** worksheets, based on an IF function, and calculates the offsite submersion dose (rem) to each organ for each Category 2 event, per the method in Section 2.2. The offsite submersion dose (rem) attributed to a specific event is equal to the submersion dose rate (rem-m^3/FA-s) multiplied by the number of fuel assemblies (FA) involved in the event, release fraction, mitigation factor, and χ/Q (s/m^3).

- ***Gonad***: This worksheet calculates the offsite inhalation dose (rem) to the gonad. This worksheet collects the appropriate inhalation dose for each nuclide grouping from the Grouped Sources worksheet and the number of fuel assemblies involved, release fraction, mitigation factor, breathing rate, and χ/Q values from the ***Inputs*** worksheet, based on the user-selected inputs. The inhalation dose to the gonad for each nuclide group is equal to the product of all these inputs (i.e., Source Term x Number of FAs x Release Fraction x Mitigation Factor x Breathing Rate x χ/Q). The total offsite inhalation dose (rem) to the gonad is calculated as the sum of each nuclide group total.

- ***Breast, Lung, Marrow, Bone Surface, Thyroid, Remainder,*** **and** ***Whole Body*** **Worksheets:** Each of these worksheets is identical to the ***Gonad*** worksheet, except that the inhalation dose (rem/FA) from the ***Grouped Sources*** worksheet is selected based on that particular organ.

- ***Input***: Contains the input parameters for calculating offsite dose consequences due to Category 2 DBEs. Input fields include the fuel type (e.g., average PWR, average BWR, max PWR, max BWR), event number, whether or not the event occurs in a pool, HEPA mitigation (i.e., with or without HEPA filtration), χ/Q distance (e.g., 8-km or 11-km), breathing rate (m^3/s), and whether a ground release is assumed (yes or no). Calculated fields include the event description, event frequency, number of damaged assemblies involved, mitigation factor, and χ/Q value. The calculated fields are either VLOOKUP

functions from the range "Event_desc" or "IF" functions based on the input variables selected.

- **Summary:** This worksheet contains a per event summary of each organ inhalation dose (rem/event) and organ submersion dose (rem/event), and calculates the DDE, CDE, CEDE, TEDE, eye dose, and skin dose in accordance with Section 2.2.

- **Test Cases:** This worksheet includes validation test cases for unique formulas used in this Attachment. Included are the applicable cells for which the formulas apply, test input values, computer-generated output, and output generated by hand calculation for verification.

Attachment XI –Dose Comparison of MOX PWR SNF and Maximum PWR SNF – Calculates the offsite dose consequences to the public resulting from Category 2 DBEs with high burnup MOX fuel. The worksheets contained in this file are identical to those in Attachment X with one exception, the ***Avg Dose*** and ***Max Dose*** source term worksheets are replaced by ***MOX Dose***. The MOX source terms are from the draft EIS for the MGR (DOE 1999).

4.3 MODELS

No models, as defined by AP-SI.1Q, are used in this analysis.

5. CALCULATION

5.1 CALCULATION DESCRIPTION

5.1.1 Category 1 Events

Annualized Category 1 doses to an individual receptor at the site boundary are calculated based on the applicable assumptions in Section 3 and input parameters in Section 5.2. The Category 1 dose assessment includes contributions from three sources:

- Routine radiological releases from the surface facilities
- Routine radiological releases from the subsurface facility
- Category 1 DBEs – event sequences expected to occur one or more times before permanent closure (i.e., frequency $\geq 10^{-2}$ per year)

The total estimated release from the surface facilities (4,010 Curies per year) is due entirely to Kr-85 releases from the WHB, as indicated in Section 5.2.13 (CRWMS M&O 2000a). The Waste Treatment Building is not expected to generate significant radiological emissions, based on current, best-available information (CRWMS M&O 2000a).

The total routine releases (Ci/yr) expected from the subsurface facility are shown in Section 5.2.14 (CRWMS M&O 2000b). Subsurface releases are due to radionuclides generated by activation of air (Ar-41 and N-16) and dust (N-16, Na-24, Al-28, Si-31, K-42 and Fe-55). Nitrogen-16, Aluminum-28 and Potassium-42 were not considered in the GENII-S dose assessment because they are not included in the default GENII-S radionuclide libraries.

However, their releases and half-lives are so small that their annual offsite dose contributions are insignificant. Iron-55 (Fe-55) is the only subsurface radionuclide released that has a half life measured in years (2.73), but its total annual Curie release (1.492×10^{-4}) is insignificant compared to Curie releases from Category 1 DBEs (Attachment IX).

Surface and subsurface routine releases (Ci/yr) were inputs to the Category 1 chronic offsite dose calculation performed using the GENII-S code (Attachment IV).

Category 1 DBE releases (Attachment IX) were calculated based on the event frequencies (events/yr) and event source terms (Ci/event) described in Attachments VII and VIII, respectively. Radiological releases due to Category 1 events are annualized by multiplying the expected release from each event by the event frequency, as indicated by Equation (3) of Section 2.2.

Using the aforementioned annual releases as input, the annual offsite TEDE dose is calculated for a receptor at the site boundary using the methodology described in Attachment IV. The results of the Category 1 dose calculations are provided in Section 6.1.1.

5.1.2 Category 2 Events

The Category 2 TEDE dose (Equation 4) to an individual receptor at the site boundary is calculated based on the methodology in Section 2.2, applicable assumptions in Section 3, and applicable input parameters in Section 5.2. Category 2 doses are calculated on a per event basis for each of the Category 2 DBEs identified in Attachment VII. Details of the Category 2 dose calculations are provided in Attachment X. A summary of the results is presented in Section 6.1.2.

5.2 INPUT PARAMETERS

5.2.1 Inhalation and air submersion DCFs are taken from Federal Guidance Report 11 (Eckerman et al. 1988) and Federal Guidance Report 12 (Eckerman and Ryman 1993), respectively. The DCFs used in this analysis are listed in Attachment VIII. The Sv/Bq to rem/Ci unit conversion factor is taken form Federal Guidance Report 11 (Eckerman et al. 1988).

Basis: *Federal Guidance Report No. 11, Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion* (Eckerman et al. 1988) and *External Exposure to Radionuclides in Air, Water, and Soil* (Eckerman and Ryman 1993).

Input Status: N/A - Accepted Data (AMOPE Approved). OPE: ERC-2089 and ERC-2090.

5.2.2 Atmospheric dispersion factors of 4.77×10^{-4} sec/m^3, 2.98×10^{-7} sec/m^3 and 1.99×10^{-7} sec/m^3 are used to calculate offsite doses at 100 meters, 8,000 meters and 11,000 meters (Assumption 3.3), respectively, due to chronic (Category 1) releases. Atmospheric dispersion factors of 2.94×10^{-5} sec/m^3 and 2.17×10^{-5} sec/m^3 are used to

calculate offsite doses at 8,000 meters and 11,000 meters (Assumption 3.3), respectively, due to acute (Category 2 event) releases.

Basis: The chronic and acute atmospheric dispersion factors (χ/Q values) are based on Yucca Mountain site-specific data as documented in *Calculations of Acute and Chronic "Chi/Q" Dispersion Estimates for a Surface Release* (CRWMS M&O 1999c). Chronic χ/Q values are based on the maximum wind sector (Sector 16) at each distance. Acute χ/Q values are based on the 99.5 percentile values at each distance, which corresponds with Wind Sector 14 (West-Northwest to East-Southeast). This technical product input requires confirmation before the dose calculation results can be qualified.

Input Status: Unqualified (CRWMS M&O 1999c).

5.2.3 An acute breathing rate of 3.3×10^{-4} m^3/s is used for non-involved worker dose calculations and Category 2 public dose calculations. A chronic breathing rate of 2.662×10^{-4} m^3/s is used in Category 1 dose calculations for a public receptor at the site boundary.

Basis: This acute breathing rate is based on the NRC-recommended worker breathing rate specified in NUREG-1536, *Standard Review Plan for Dry Cask Storage Systems* (NRC 1997). This breathing rate is based on the volume intake of air for "light activity" and is considered to be appropriate for DBE accident scenarios resulting in short-term exposures to workers or the public. This breathing rate is based on the breathing rates for Reference Man originally recommended in ICRP-23 (ICRP 1975). The chronic breathing rate is based on the default value in the approved GENII-S code (CSCI: 30034 V1.4.8.5) (CRWMS M&O 1998c).

Input Status: N/A – NRC Guidance/Codes & Standards.

5.2.4 PWR and BWR radionuclide inventories (units of Curies per fuel assembly) for fuel with Average and Maximum characteristics (see Section 2.2.1) are from *PWR Source Term Generation and Evaluation* (CRWMS M&O 1999h) and *BWR Source Term Generation and Evaluation* (CRWMS M&O 1999b). These technical product inputs require confirmation before the dose calculation results can be qualified.

Input Status: Unqualified (CRWMS M&O 1999h and CRWMS M&O 1999b).

5.2.5 The failure probability of the HVAC system to filter radiological releases from the WHB is 1.72×10^{-7}.

Basis: This is the conditional probability that the HVAC system will be unavailable to filter radiological releases in the WHB, with a 24-hour mission time, following a design basis event. This probability was developed in *Reliability Assessment of Waste Handling Building HVAC System* (CRWMS M&O 1999i), based on the HVAC system design for the Viability Assessment (VA). This technical product input requires confirmation before the dose calculation results can be qualified.

Input Status: Unqualified (CRWMS M&O 1999i).

5.2.6 CSNF fuel assemblies have the following surface areas:

PWR = 449,003 cm^2/assembly
BWR = 168,148 cm^2/assembly

Basis: These surface areas are bounding estimates based on the assemblies with the highest known surface areas, a South Texas PWR assembly (CRWMS M&O 1999h) and a ANF 9x9 JP-4 BWR assembly (CRWMS M&O 1999b). These technical product inputs require confirmation before the dose calculation results can be qualified.

Input Status: Unqualified (CRWMS M&O 1999h and CRWMS M&O 1999b).

5.2.7 CSNF fuel assemblies have the following initial crud activities at the time of discharge from the reactor:

PWR	BWR
Co-60 = 140 $\mu Ci/cm^2$	Co-60 = 1254 $\mu Ci/cm^2$
Fe-55 = 5902 $\mu Ci/cm^2$	Fe-55 = 7415 $\mu Ci/cm^2$

Basis: These crud activities are bounding estimates based analysis in *Commercial SNF Accident Release Fractions* (CRWMS M&O 1999d). This technical product input requires confirmation before the dose calculation results can be qualified.

Input Status: Unqualified (CRWMS M&O 1999d).

5.2.8 The waste handling rates used to estimate design basis event frequencies are shown in Table 2.

Table 2 – Waste Handling Rates at the MGR

Parameter	Value
Peak # shipping casks handled/yr	620
BWR SFAs/yr	7,800
PWR SFAs/yr	5,000
Total failed fuel SECs projected	6,400

Basis: *1999 Design Basis Waste Input Report for Commercial Spent Nuclear Fuel* (CRWMS M&O 1999a). This report was prepared in accordance with PRO-TS-003 Rev 01, a procedure not subject to Quality Assurance Requirements and Description (QARD) requirements. This technical product input requires confirmation before the dose calculation results can be qualified.

Input Status: Unqualified (CRWMS M&O 1999a).

5.2.9 A drop rate of 1.8×10^{-5} drops per lift is used to calculate the frequency of SFA and SFA basket drops involving CSNF.

Basis: This drop rate is based on fuel assembly drops at commercial nuclear reactor facilities (as reported in Licensee Evaluation Reports) during the period from 1970 through 1991, as documented in *Waste Package Design Basis Events* (CRWMS M&O 1997). Application of this drop rate to the SNF lifts at the MGR is considered reasonable based on the similarity of the fuel handling equipment and the level of quality controls expected. This technical product input requires confirmation before the dose calculation results can be qualified.

Input Status: Unqualified (CRWMS M&O 1997).

5.2.10 A drop rate of 1.4×10^{-5} drops per lift is used to calculate the frequency of cask drops and DC/WP drops.

Basis: This drop rate is based on heavy-lift crane data from the Newport News Shipbuilding facility (CRWMS M&O 1998b). Application of this drop rate to DC/WP lifts at the MGR is considered reasonable based on the similarity of the crane sizes and the object masses to be lifted. This drop rate may be conservative given the fact that bridge cranes at the MGR are expected to be subject to more restrictive quality and operational controls than the cranes typically used at commercial shipyards. This technical product input requires confirmation before the dose calculation results can be qualified.

Input Status: Unqualified (CRWMS M&O 1998b).

5.2.11 The independent, random failure rate of an active electrical or mechanical component is 5.0E-05/hr.

Basis: This component failure rate is based on analysis of equipment drops onto a WP in CRWMS M&O (1997). This failure rate is multiplied by the operational time that an overhead crane is suspended above SNF to calculate the probability of a yoke drop onto SNF in Attachment VI. This technical product input requires confirmation before the dose calculation results can be qualified.

Input Status: Unqualified (CRWMS M&O 1997).

5.2.12 The CSNF release fractions in air, for Category 2 dose assessment, are shown in Table 3.

Table 3 – CSNF Release Fractions in Air for Category 2 Events

Nuclide	Airborne Release Fraction (ARF)	Respirable Fraction (RF)	Effective Release Fraction
H-3	0.3	1.0	0.3
Kr-85	0.3	1.0	0.3

I-129	0.3	1.0	0.3
Cs	2.0E-04	1.0	0.0002
Sr	3.0E-05	5.0E-03	1.5E-07
Ru	3.0E-05	5.0E-03	1.5E-07
Crud	1.0E+00	3.0E-01	0.3
Particulates	3.0E-05	5.0E-03	1.5E-07

Basis: These release fractions are conservative estimates based on analysis in *Commercial SNF Accident Release Fractions* (CRWMS M&O 1999d). This technical product input requires confirmation before the dose calculation results can be qualified.

Input Status: Unqualified (CRWMS M&O 1999d).

5.2.13 The total estimated release from the surface facilities, due to normal operations, is 4,010 Curies per year.

Basis: This release was estimated by Surface Design based on the postulated failure of PWR and BWR spenf fuel assemblies during normal handling operations (CRWMS M&O 2000a). The estimated release is due entirely to Krypton-85 emissions from the WHB. This input does not require confirmation because the normal releases from the surface facilities are significantly less than the anticipated annual releases due to Category 1 DBEs and have a negligible impact on the calculation results.

Input Status: N/A – Reference Only.

5.2.14 The total estimated releases from the subsurface facilities, due to normal operations, are shown in Table 4.

Table 4 – Annual Releases from the Subsurface Due to Normal Operations

Routine Release - Subsurface (Ci/yr)		Half Life ($T_{1/2}$)
Activated Air		
N-16	2.909×10^{-3}	7.13 sec
Ar-41	$5.728 \times 10^{+1}$	1.82 hr
Activated Dust		
N-16	1.189×10^{-8}	7.13 sec
Na-24	6.471×10^{-3}	14.96 hr
Al-28	3.963×10^{-3}	2.25 min
Si-31	7.170×10^{-4}	2.62 hr
K-42	8.041×10^{-4}	12.36 hr
Fe-55	1.492×10^{-4}	2.73 yr

Basis: This release was estimated by Subsurface Design based on the postulated activation of air and dust in the subsurface facilities during normal operations (CRWMS M&O 2000b). This input does not require confirmation because the

normal releases from the subsurface facilities are significantly less than the anticipated annual releases due to Category 1 DBEs and have a negligible impact on the calculation results.

Input Status: N/A – Reference Only.

5.2.15 The radionuclide activities (Ci/FA) used to compare commercial PWR fuel with MOX fuel are based on values for high-burnup PWR MOX fuel from the Draft EIS (DOE 1999).

Basis: Radionuclide activities for high-burnup PWR MOX fuel bounds those of typical BWR MOX fuel, which was also presented in the Draft EIS (DOE 1999). This technical product input requires confirmation before the dose calculation results can be qualified.

Input Status: Unqualified (DOE 1999).

6. RESULTS

This document and its results may be affected by technical product input information that requires confirmation. Any changes to the document or its results that may occur as a result of completing the confirmation activities will be reflected in subsequent revisions. The status of the input information quality may be confirmed by review of the Document Input Reference System database.

6.1 DOSE CALCULATION RESULTS

6.1.1 Category 1 Results

The Category 1 events, excluding normal operations, that were considered in this calculation are shown in Table 5. Also indicated in Table 5 is whether the event occurs in a pool, the maximum potential number of PWR and BWR fuel assemblies at risk, and the sequence frequency for each Category 1 event.

Table 5 – Category 1 Events Analyzed

Event #	Category 1 Events	Occurs in Pool?	Material at Risk (# SFAs)		Sequence Frequency (per year)
			PWR	BWR	
1-01	SFA Drop Onto Another SFA in Cask	Y	2	2	2.34E-01
1-02	SFA Collision	Y	1	1	3.90E-02
1-03	SFA Drop Onto Empty Basket	Y	1	1	4.22E-02
1-04	SFA Drop Onto Another SFA in Basket Staging Rack (Lowering Into)	Y	2	2	1.92E-01
1-05	Basket Drop Onto Another Basket in Basket Staging Rack (Lifting Out)	Y	8	16	4.10E-02
1-06	Basket Drop Onto Another Basket in Pool (Transfer Into Pool Storage)	Y	8	16	4.10E-02

1-07	Basket Drop Onto Another Basket in Pool (Transfer Out of Pool Storage)	Y	8	16	4.10E-02
1-08	Basket Drop Onto Transfer Cart or Pool Floor	Y	4	8	4.10E-02
1-09	Basket Drop Back Into Pool	Y	4	8	4.10E-02
1-10	Basket Drop Onto ATS Hot Cell Floor	N	4	8	4.10E-02
1-11	Basket Drop Onto Another Basket in Dryer	N	8	16	4.10E-02
1-12	SFA Drop Onto Another SFA in Dryer	N	2	2	2.34E-01
1-13	SFA Drop Onto ATS Hot Cell Floor	N	1	1	2.34E-01
1-14	SFA Drop Onto Another SFA in DC	N	2	2	2.34E-01

The offsite public dose consequences for Category 1 events are based on methodology in Section 2 and Attachment IV, applicable assumptions in Section 3, applicable input parameters in Section 5.2, and calculations in Attachments VII-IX. In general, the annualized Category 1 offsite doses are based on the following:

- Chronic exposure over a period of 1 year.
- Frequency weighted doses.
- Inhalation, ingestion, submersion and groundshine pathways.
- Mitigated (HEPA-filtered) particulate releases from the surface facilities (Assumption 3.23).
- Maximum sector chronic χ/Q.
- χ/Q distance of 11-km from the WHB to the site boundary (surface releases) and 8-km from the potential repository to the site boundary (subsurface release).

The total Category 1 dose was based on contributions from six nuclide groups, which constituted individual calculation runs in GENII-S. The six nuclide groups and a description of each is given in Table 6 below.

Table 6 – GENII-S Runs

GENII-S Runs	Nuclides Included	Group Description
PRCHSF	Kr-85	Chronic release from the surface facilities due to normal operations
PRCHSB	Ar-41, Na-24, Si-31 and Fe-55	Chronic release from the subsurface facility due to normal operations
PRCHGS	H-3, I-129, Kr-85	Annualized release of gaseous radionuclides due to all Category 1 DBEs
PRCHP1	Cl-36, Fe-55, Co-60, Se-79, Zr-93, Nb-93m, Nb-94, Ru-106, Pd-107, Cd-103m, Sb-125, Sn-126, Pm-147, Sm-151, Eu-154, Eu-155, Cm-242, Cm-243, Cm-244, Cm-245, and Cm-246	Annualized release of selected particulate radionuclides due to all Category 1 DBEs (transfer coefficient file FTRANS.DAT)
PRCHP2	C-14, Ni-63, Sr-90, Tc-99, Cs-137, Ac-227, Pa-231, U-232, U-233, U-234, U-236, U-238, Np-237, Pu-238, Pu-239, Pu-240, Am-241, and AM-243	Annualized release of selected particulate radionuclides due to all Category 1 DBEs (transfer coefficient file FTRANRR.DAT)
PRCHP3	Ni-59, Cs-134, Cs-135, Th-230, U-235, Pu-241, Pu-242	Annualized release of selected particulate radionuclides due to all Category 1 DBEs (transfer coefficient file FTRANRR.DAT)

The annualized Category 1 doses to the public due to inhalation, ingestion, submersion and

groundshine pathways are presented in Table 7 along with the annual TEDE dose.

Table 7 – Annual Public Doses Due to Category 1 Events

GENII-S Run	Inhalation Effective Dose Equivalent (rem/yr)	Ingestion Effective Dose Equivalent (rem/yr)	External Dose (rem/yr)	Annual TEDE Dose (rem/yr)[1]	Percentage of TEDE Dose Total (%)[2]
PRCHSF	0	0	2.5×10^{-7}	2.5×10^{-7}	0.4%
PRCHSB	4.5×10^{-10}	2.1×10^{-10}	2.9×10^{-6}	2.9×10^{-6}	4.7%
PRCHGS	6.6×10^{-7}	0	8.6×10^{-8}	7.4×10^{-7}	1.2%
PRCHP1	6.4×10^{-6}	7.1×10^{-7}	8.7×10^{-8}	7.2×10^{-6}	11.6%
PRCHP2	3.7×10^{-5}	1.0×10^{-5}	1.5×10^{-7}	4.7×10^{-5}	75.7%
PRCHP3	3.7×10^{-6}	2.2×10^{-7}	2.1×10^{-10}	4.0×10^{-6}	6.4%
Totals:	**4.8×10^{-5}**	**1.1×10^{-5}**	**3.5×10^{-6}**	**6.2×10^{-5}**	

[1] Annual TEDE dose for each GENII-S run is the sum of the inhalation effective dose equivalent, ingestion effective dose equivalent and external dose.

[2] Dose percentage shown is the ratio of the TEDE dose per run to the total TEDE dose for all runs.

The expected annual dose to a non-involved worker located 100 meters from the release point was calculated for all Category 1 releases, including normal operational releases from the surface and subsurface facilities. The dose calculation for the non-involved worker assumes that a single worker receives a chronic exposure, at 100-m distance, from each potential Category 1 event and the normal releases in a single year. This calculation of the non-involved worker dose is conservative and does not account for worker training, administrative controls, or emergency response procedures to minimize worker exposures to Category 1 DBEs. The non-involved worker doses are based on the methodology in Section 2, applicable assumptions in Section 3, applicable input parameters in Section 5.2, and calculations in Attachment V. In general, the annualized worker doses are based on the following:

- Chronic exposure over a period of 1 year.
- Frequency weighted dose contributions from Category 1 DBEs.
- Submersion dose only for normal surface and subsurface releases. Submersion doses dominate inhalation doses for normal releases due to the source term of Kr-85 from the surface and Ar-41 from the subsurface facilities.
- Inhalation and submersion pathways only. Ingestion and ground contamination pathways are not included because there will be no ingestible crops produced onsite and the radiation protection program will prevent worker exposures to contaminated soil.
- Mitigated (HEPA-filtered) particulate releases from the surface facilities (Assumption 3.23).
- Maximum sector chronic χ/Q
- χ/Q distance of 100-m from the WHB (surface release) or the subsurface repository (subsurface release) to the nearest non-involved worker.

The annual non-involved worker doses at 100-m due to inhalation and submersion pathways are presented in Table 8.

Table 8 – Annual Non-Involved Worker Doses Due to Category 1 Events

Release Type	TEDE (rem/yr)	CDE_{max}+DDE (rem/yr)	Skin Dose (rem/yr)
Summation of Category 1 DBEs	4.11×10^{-3}	9.08×10^{-2}	3.06×10^{-2}
Normal Surface Releases	8.42×10^{-4}	8.42×10^{-4}	9.34×10^{-2}
Normal Subsurface Releases	6.57×10^{-3}	6.57×10^{-3}	1.02×10^{-2}
Totals:	**1.15×10^{-2}**	**9.82×10^{-2}**	**1.34×10^{-1}**

6.1.2 Category 2 Results

The offsite public dose consequences for Category 2 events are based on methodology in Section 2, applicable assumptions in Section 3, applicable input parameters in Section 5.2, and calculations in Attachments VII, VIII and X. In general, the Category 2 offsite doses are based on the following:

- Acute exposure (2-hour) to radioactive plume.
- Inhalation and submersion pathways only (see Equations 4 and 5).
- Release fraction that includes credit for the respirable fraction of particulates.
- Mitigated (HEPA-filtered) particulate releases from the surface facilities (Assumption 3.23).
- χ/Q distance of 11,000 meters from the WHB to the site boundary (surface releases) and 8,000 meters from the potential repository to the site boundary (subsurface release).

The mitigated, offsite public dose consequences for Category 2 DBEs are summarized in Table 9.

Table 9 – Mitigated Public Dose Consequences for Category 2 DBEs

Event No.	Description	Sequence Frequency (per year)	SFAs Breached	Skin Dose (rem)	Max Organ Dose[2] (rem)	TEDE Dose[1] (rem)
2-01	SFA Basket Collision During Transfer to Pool Storage[3]	6.83×10^{-3}	4-PWR	7.16×10^{-3}	2.00×10^{-3}	3.74×10^{-4}
2-02	SFA Basket Collision During Transfer to Incline Transfer Canal[3]	6.83×10^{-3}	4-PWR	7.16×10^{-3}	2.00×10^{-3}	3.74×10^{-4}
2-03	Uncontrolled Descent of Incline Transfer Cart[3]	6.83×10^{-3}	4-PWR	7.16×10^{-3}	2.00×10^{-3}	3.74×10^{-4}
2-04	Handling Equipment Drop onto SFA in Pool[3]	2.38×10^{-3}	1-PWR	1.79×10^{-3}	5.00×10^{-4}	9.36×10^{-5}
2-05	Handling Equipment Drop onto SFA in Hot Cell	2.38×10^{-3}	1-PWR	1.79×10^{-3}	3.28×10^{-3}	7.46×10^{-4}
2-06	Handling Equipment Drop onto SFA Basket in Pool[3]	1.74×10^{-3}	4-PWR	7.16×10^{-3}	2.00×10^{-3}	3.74×10^{-4}
2-07	Handling Equipment Drop onto SFA Basket in Hot Cell	6.95×10^{-5}	8-BWR	5.16×10^{-3}	1.29×10^{-2}	2.78×10^{-3}
2-08	Unsealed DC Collision	1.80×10^{-3}	44-BWR	2.84×10^{-2}	7.12×10^{-2}	1.53×10^{-2}
2-09	Unsealed DC Drop and Slapdown	8.40×10^{-3}	44-BWR	2.84×10^{-2}	7.12×10^{-2}	1.53×10^{-2}
2-10	Handling Equipment Drop onto Unsealed DC	1.10×10^{-4}	44-BWR	2.84×10^{-2}	7.12×10^{-2}	1.53×10^{-2}
2-11	Shipping Cask Drop into Cask Preparation Pit	8.68×10^{-3}	68-BWR	4.39×10^{-2}	1.10×10^{-1}	2.36×10^{-2}
2-12	Shipping Cask Drop into Cask Unloading Pool[3]	8.68×10^{-3}	68-BWR	4.39×10^{-2}	1.35×10^{-2}	2.39×10^{-3}
NM-01	Non-Mechanistic Shipping Cask Leak[4]	NC	68-BWR	4.39×10^{-2}	1.35×10^{-2}	2.39×10^{-3}
NM-02	Non-Mechanistic Preclosure Early Failure of a WP[4]	NC	21-PWR	5.09×10^{-2}	1.42×10^{-2}	2.66×10^{-3}

[1] TEDE dose is equal to CEDE+DDE (Equation 4).
[2] Maximum organ dose is equal to CDE_{max}+DDE (Equation 5).
[3] Denotes a pool event.
[4] Unmitigated (i.e., no HEPA filtration assumed) release of noble gases only.
NC = Not Calculated

6.2 DISCUSSION OF RESULTS BASED ON UNQUALIFIED DATA OR INPUTS

The design basis events and event frequencies identified in this calculation are based on a surface facility design (CRWMS M&O 2000d) and concept of operations that is unqualified and subject to change.

The waste receipt/handling rates used for shipping casks, CSNF assemblies, and DCs/WPs are based on unqualified data and subject to further confirmation before the calculation results can be qualified.

The number of lifts assumed for DCs, SFAs, SFA baskets, and shipping casks are based on unqualified data that is subject to change in the future. The number of lifts for each waste form has a direct impact on event frequencies and, therefore, could impact the frequency results as well as the annualized Category 1 event dose.

The drop frequencies for SFA lifts, SFA basket lifts, and heavy lifts involving DCs and shipping casks are based on unqualified data. These drop frequencies have a direct impact on the event frequencies calculated and, therefore, must be confirmed before the calculation results can be qualified.

The CSNF crud surface activities and release fractions in air are based on a technical product input that is unqualified and subject to further confirmation. The offsite dose calculations are sensitive to both of these parameters and a change in either could impact the calculation results.

The assumption that the MGR will be designed to prevent a credible breach of a sealed shipping cask or WP containing commercial SNF is based on unqualified data that is subject to confirmation. Confirmation of this assumption is predicated on demonstrating that the facility design, in conjunction with a sealed shipping cask or WP, will ensure that a breach resulting in radiological release is incredible. Failure to verify this assumption could result in sealed shipping cask and WP events, which are currently BDBEs, being re-classified as Category 1 or Category 2 DBEs.

Several of the input parameters used in the GENII-S code to calculate Category 1 offsite doses to the public are based on unqualified data that is subject to verification. The GENII-S input data (Attachment IV), if changed, could potentially impact the Category 1 dose results.

The maximum MAR assumed for dose assessment is based on unqualified data that is subject to confirmation. This assumption has a direct impact on the doses calculated for Category 1 and Category 2 events. Although these parameters were conservatively selected, any increase in the MAR would increase the calculated offsite dose for a given event.

The HVAC system reliability and the probability of an unfiltered release from the WHB are based on technical product inputs that are unqualified and subject to confirmation. A change in this data could alter the categorization (i.e., Category 1, Category 2, or BDBE) of events identified in this calculation.

The HEPA filter efficiency assumed for cesium releases is based on unqualified data that is subject to confirmation. This parameter could impact the Category 1 dose results because Cs-137 is the primary contributor to the total effective ingestion dose calculated by GENII-S (Attachment IV).

The preclosure period of 100 years is an unqualified assumption that is subject to confirmation. If the preclosure period were to change, it would impact the DBE frequency cutoffs and could alter the categorization of events identified in this calculation.

The assumption that shipping casks will not breach if dropped from the normal lift heights during handling operations is an assumption that must be confirmed before the calculation results can be qualified.

The random failure rate of an active electrical or mechanical component, used to calculate the probability of a yoke drop onto SNF, is based on unqualified data that is subject to confirmation.

The PWR and BWR radionuclide inventories used to calculate DBE source terms are based on unqualified data that is subject to confirmation. A change in this data would impact the dose calculation results.

The atmospheric dispersion factors used to calculate doses to the public and non-involved workers are based on unqualified data that is subject to confirmation. A change in this data would impact the dose calculation results.

6.3 DISCUSSION OF UNCERTAINTIES AND CONSERVATISM

This calculation includes a number of parameters that are not very well known (i.e., have a high degree of uncertainty), have been conservatively selected, or are not sensitive to the results. Calculation parameters which fall into one or more of these categories are discussed below.

MGR Handling Rates: Maximum handling rates for any given year are assumed. This is very conservative as it assumes the maximum number of assemblies, casks, WPs, etc. that could occur in any year actually occur during every year of operation. This tends to overstate event frequencies and has a direct impact on the annual Category 1 event releases. Whereas the maximum number of SFAs handled per year is 13,013, the average number of assemblies handled per year is 9,940 (equal to the total number of assemblies and failed fuel canisters received over the lifetime of the facility divided by 30 years)(CRWMS M&O 1999a), a factor of 1.31.

Drop Frequencies: The drop frequency for spent fuel assemblies and assembly baskets, 1.8×10^{-5} drops per lift, is based on historical information from nuclear power plant operations from 1970 through 1991 . This number is based on an estimate of the total number of handlings and considers several events that did not result in a radiological release. By comparison, this calculation assumes that all drops result in a release. It is also likely that a more recent compilation of drop events at commercial nuclear power plants would result in a lower drop frequency due to the maturity of the industry and the greater emphasis on quality control in recent years. However, it could be argued that the MGR operations will not have the experience base of operating reactors and, furthermore, the number of MGR fuel handlings in a typical year will far exceed the average number of fuel handlings at an operating reactor. An order of magnitude decrease in the drop frequency would move the frequency of assembly basket events from Category 1 to Category 2.

The crane drop frequency for shipping cask lifts and DC lifts (1.4×10^{-5} drops/lift) is also based on historical information (from Newport News Shipbuilding) on similar type cranes (Section 5.2.10) in a production environment. This drop frequency is a conservative estimate of the reliability of commercially-available cranes produced to standard industry specifications. A decrease in the reliability (increase in the drop frequency) of the cask and DC bridge cranes could move the frequency of cask and DC drop events from Category 2 to Category 1. An increase in crane reliability would likely not affect the frequency category for cask and DC drop events and only improve the safety margin (e.g., from a borderline Category 1-Category 2 event to an event well below the Category 1 frequency cutoff).

Preclosure Operational Period: A preclosure operational period of 100 years was assumed (Assumption 3.27) in order to determine the cutoff frequency between Category 1 and Category 2 events. Per the proposed 10 CFR 63, a Category 1 event is any event expected to occur one or more times before permanent closure of the repository and Category 2 events are those events having at least a 1 in 10,000 probability of occurring before permanent closure. If the period before permanent closure is defined as 100 years, the cutoff frequency between Category 1 and Category 2 events is 10^{-2} per year, and the lower frequency limit for Category 2 events is 10^{-6} per year. If, however, the preclosure period is changed it will directly affect the cutoff frequencies used in Attachment VII to determine event categories. For example, if the preclosure period was extended to 150 years, the frequency range for Category 2 events would be 6.67×10^{-7} to 6.67×10^{-3} per year.

For surface emplacement operations, the preclosure period is approximately 30 years. Therefore, using a 100-year preclosure period is conservative for assessing Category 1 events. During the time period from 30 years to 100 years (i.e., after emplacement), the waste handling operations are complete and no significant movement of waste is expected. Therefore, the only events of significance are external events and rockfall, and the WP and other engineered features are designed to withstand all external events and credible rockfall scenarios.

Material-At-Risk: The MAR assumed in each of the event scenarios is conservative. All bare fuel events assumed the maximum number of PWR or BWR assemblies or baskets that could potentially be involved. DC events were assumed to occur with 21-PWR or 44-BWR assemblies. Shipping cask events are especially conservative in assuming that 24-PWR or 68-BWR CSNF assemblies are involved. In reality, the probability that an actual event will occur with the maximum MAR is less than one. This parameter has a small effect on the results obtained.

Maximum Radionuclide Inventories: Category 2 events were assumed to include the maximum radionuclide inventories for CSNF (Section 2.2.1). This is a conservative assumption because the actual percentage of all CSNF fuel assemblies having the maximum fuel characteristics is very small. This parameter has a small effect on the results obtained.

Decay Time: The 5-year decay time assumed for the conservative dose estimates of Category 2 events is very conservative because few, if any, assemblies are expected to be received at the MGR after such a short decay time. The dose calculations herein assume that all Category 2 events occur with the maximum radionuclide source term, using a 5 year decay time. This parameter has a small effect on the results obtained.

Crud activity: Crud activities (Co-60 and Fe-55) are conservatively calculated because the existing CSNF assemblies are not well characterized with respect to crud, and the existing data on crud activities varies widely. Historically, crud contributions to the offsite dose have not been included in safety analysis reports of NRC-regulated or DOE-owned sites. The crud source term has a dominant effect on the offsite dose due to dry Category 2 events with Maximum BWR fuel (5-year decay) because of the large crud activity assumed for BWR fuel and the very short decay time. However, the crud source terms used in this calculation are very conservative and any future change will likely be a decrease in the surface activities or a decrease in the release fraction that is assumed to become airborne following an event.

Crud surface area: Crud surface areas are based on the commercial PWR and BWR assemblies with the largest surface areas (CRWMS M&O 1999h and 1999b). This is a conservative assumption since it implies that all releases will involve assemblies with the maximum surface area. This parameter has a small effect on the results obtained.

Damage Fraction: The damage fraction is conservatively assumed to be 1.0 (Assumption 3.20). This assumes that all events will result in the breach of 100% of the fuel rods involved. A damage fraction of 1.0 is conservatively assumed because there is little data on the structural capability of irradiated spent fuel rods. In all likelihood, most of the energy involved in a SFA drop event would be absorbed by the structural members of the SFA or the energy of impact would be focused on a small fraction of the rods. In either case, the fraction of rods that would breach in a drop event is expected to be much less than 1.0.

For cask events and DC events, the damage fraction is even more conservative. The cask and the DC are both very massive and can reasonably be expected to absorb a fraction of the impact energy associated with a drop, slapdown or collision. In effect, the 100% damage fraction implies that all of the impact energy is transferred directly to the bare fuel inside. Furthermore, 46.5% (CRWMS M&O 1999a) of the CSNF received at the MGR will be enclosed in Dual Purpose Canisters (DPCs) contained within shipping casks. These DPCs will not be cut opened until the cask has been lowered into the cask unloading pool. Therefore, the dose assessment for the cask drop into the Cask Preparation Pit (Table 9, Event 2-11), which involves 68-BWR SFAs and results in the bounding offsite dose, is very conservative. The dose assessment takes no credit for the structural integrity of the DPC to confine radionuclides during a drop into the Pit or, at a minimum, absorb some of the energy at impact. The damage fraction parameter could lower the offsite dose results if a basis was established for a more reasonable fraction. Also, the frequency of a cask drop with bare fuel could potentially be reduced by a factor of 2 by simply crediting the fraction of casks that arrive with fuel contained in DPCs.

Cladding Release Fraction: The release fraction of radionuclides from the gap between the fuel rod and cladding is conservatively assumed to be 1.0 (Assumption 3.20). This assumes that when a fuel rod is breached, 100% of the fission products and particulates contained in the fuel-cladding gap are available for release to the surrounding environment. This is very unlikely given that most breaches will be pinhole ruptures or small breaks in the cladding. It is unlikely that there would be a sufficient motive force to drive all of the particulates out of the fuel-clad gap along the entire length of the fuel rod. More likely, a large fraction of the particulates would never make it to the breach point and remain within the cladding. This parameter has a small effect on the results obtained because the HEPA filtration removes 99% of the particulates.

Airborne Release Fraction: The ARF values used in this calculation are considered conservative for the accident conditions expected at the MGR. These values were established based on NRC licensing precedence and comparison with more recent DOE analyses on the subject. It would require a significant change in the ARF values to impact the dose calculation results.

Local Deposition Factor: The local deposition factor is conservatively assumed to be 1.0 (Assumption 3.20). This assumes that 100% of the particulates (including crud) released during

an accident are transported to the building HVAC exhaust system. In other words, there is no gravitational settling of particulates onto available surfaces. More likely, a large fraction of the particulates would be deposited within the building and not make it to the HEPA filters. This parameter has a significant impact on dry event doses, which are dominated by particulate releases.

Plume Depletion: Depletion (gravitational settling) of the radioactive plume enroute to the offsite receptor was not considered in this calculation, nor was it factored into the Chi/Q values used to disperse the radionuclides between the facility release points and the site boundary. The use of a ground release and no plume depletion in the calculation model results in conservative doses at the site boundary.

Effective Relèase Fraction in Water: This calculation assumes that only gaseous nuclides can escape out of the pool and be released to the environment. This assumption is based on NRC precedence established in Regulatory Guide 1.25 and is expected to be reasonably conservative.

HEPA Filter Mitigation Factor: A HEPA filter particulate retention efficiency of 99% was used in this calculation, based on NRC precedence in Regulatory Guide 1.140 and Regulatory Guide 1.52. This is a very conservative number considering the fact that a single stage HEPA filter, by definition, has a minimum filtration efficiency of 99.97% for 0.3-μm particles (Burchsted et al. 1979). Furthermore, the current HVAC system design for the primary confinement area includes 3 stages of HEPA filters in series. In addition, the *Nuclear Air Cleaning Handbook* states that filters tested at the Energy Research and Development Administration (ERDA) Quality Assurance Stations in 1971 exhibited an efficiency >99.99% (Burchsted et al. 1979). The mitigation factor used (0.01) has a significant and direct impact on the dose results. Using a more realistic mitigation factor of 3×10^{-4} (i.e., 99.97% efficiency) would lower the Category 1 and Category 2 dose results by nearly two orders of magnitude.

Atmospheric Dispersion Factor: The χ/Q values for calculating Category 1 event doses are based on Yucca Mountain site-specific meteorology for a chronic release, consistent with the regulatory precedence in NUREG 0017 (Chandrasekaran et al. 1985). This approach is justified based on the intent of 10 CFR 63.111 to limit the annual dose to the public due to Category 1 events.

The chronic χ/Q values used for Category 1 doses are based on the maximum wind sector (16), which corresponds to a wind from the North-Northwest direction to the South-Southeast direction (CRWMS M&O 1999c). Although this wind direction does not correspond with the wind direction required to transport radionuclides from the MGR to the assumed dose receptor at the nearest point on the YMP Withdrawal Area boundary (East-West, Sector 5), it results in the bounding χ/Q at 8-km and 11-km. The use of this χ/Q adds conservatism to the calculation as it is almost two orders of magnitude larger than the χ/Q for the West-East wind direction (Sector 5). A West-East wind is necessary to carry releases to the nearest dose receptor on the YMP Withdrawal Area Boundary.

For Category 2 dose calculations, the 99.5% maximum acute sector (Sector 14) χ/Q values were used (CRWMS M&O 1999c). The maximum sector is used for conservatism and consistency with Regulatory Guide 1.145 even though it corresponds with a wind direction (West-Northwest

to East-Southeast) that is not in the direction of the dose receptor (Sector 5, East-West wind direction). For comparison, the 99.5% maximum acute sector χ/Q at 11-km (2.17×10^{-5} s/m^3) is a factor of 1.9 larger than the 95% overall site χ/Q value (1.15×10^{-5} s/m^3) and a factor of 3.4 higher than the 50% maximum acute sector χ/Q at the same distance. The 99.5% acute χ/Q values are very conservative and represent meteorological conditions that are exceeded only 0.5% of the time. For comparison, the 50th percentile acute χ/Q values at 8-km and 11-km are more than 3 orders of magnitude smaller than the 95th percentile acute χ/Q values at 8-km and 11-km.

Dose Receptor Distance: The distances used to calculate offsite doses to the public, 8-km for subsurface releases and 11-km for surface releases, are based on conservative estimates of the closest point beyond the proposed YMP Withdrawal Area boundary (Attachment III) that a member of the public could be standing. The dose receptor distance has a small impact on the χ/Q values used to disperse radionuclides from the source to the dose receptor. For example, the maximum acute sector χ/Q at 5-km (3.2×10^{-5} s/m^3) is less than an order of magnitude larger than the same χ/Q at 20-km (7.39×10^{-6} s/m^3) (CRWMS M&O 1999c). Therefore, this parameter has a small effect on the dose results for the public. The worker doses, however, could be adversely affected if the assumed distance of 100 meters (Assumption 3.3) was decreased.

Dose Conversion Factors: The DCFs for Category 1 inhalation doses are derived by the GENII-S code based on dosimetric methodology from ICRP 30 (ICRP 1979). GENII-S conservatively selects the largest Effective DCF value, regardless of the lung clearance class. This is a conservative approach which effectively assumes that the chemical form of each nuclide is that which results in the largest DCF. For example, with Plutonium isotopes, the Weekly (W) lung clearance class is selected for the inhalation DCF. However, most of the CSNF received at the MGR is expected to be in the oxide form, which corresponds to the Yearly (Y) lung clearance class, and the Yearly class DCF is nearly one order of magnitude smaller than the equivalent Weekly class DCF. Overall, however, the DCFs used for Category 1 and Category 2 dose assessment are not expected to significantly impact the offsite dose results.

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7.3 SOURCE DATA, LISTED BY DATA TRACKING NUMBER

MO0001YMP00001.000. Minimum Distances from Selected Yucca Mountain Project Sites to Public Lands. Submittal date: 01/26/2000 .

MO0003RIB00061.001. Input Parameter Values for External and Inhalation Radiation Exposure Analysis. Submittal date: 03/14/2000.

MO9911RIB00064.000. Environmental Transport Parameter Values for Dose Assessment. Submittal date: 11/10/1999.

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MO9912SPAING06.033. Ingestion Exposure Pathway Parameters. Submittal date: 12/22/1999.

SN0002T0512299.003. Revised Leaching Coefficients for GENII-S Code. Submittal date: 02/09/2000.

8. ATTACHMENTS

Attachment I - Electronic Files on Floppy Disk

Attachment II - Acronyms and Abbreviations

Attachment III - Proposed YMP Withdrawal Area Boundary

Attachment IV - GENII-S Dose Calculation Methodology for Category 1 Events

Attachment V - Non-Involved Worker Dose Calculations

Attachment VI - Probability of Yoke Drop Onto SNF

Attachment VII - Frequency Calculations

Attachment VIII - SR Source Term Calculations

Attachment IX - Category 1 Event Release Calculations

Attachment X - Category 2 DBE Dose Calculations

Attachment XI - Dose Comparison of MOX PWR SNF and Maximum PWR SNF

Attachment I

Electronic Files on Floppy Disk

The following electronic files, used to generate the results in this calculation, are contained on a 3.5" floppy disk attached to this document. These files were developed with Microsoft Excel 97 SR-2. For a controlled copy of the document and/or floppy disk files, contact the M&O Document Control Center @ (702) 295-7826.

Filename	File Size	Modified Date	Modified Time
Cat. 1 Worker Dose.xls	295 KB	12/3/01	12:55 pm
Frequency Calculations_Rev01.xls	86 KB	12/3/01	1:05 pm
SR Source Terms_Rev01.xls	210 KB	12/3/01	1:16 pm
SR Source Terms_MOX_Rev01.xls	75 KB	04/26/00	10:06 am
SR Cat. 2 TEDE Dose_Rev01.xls	337 KB	12/3/01	4:53 pm
SR Cat. 2 TEDE Dose_MOX_Rev01.xls	217 KB	05/22/00	1:47 pm
SR Cat. 1 Release_Rev01.xls	139 KB	12/3/01	1:46 pm

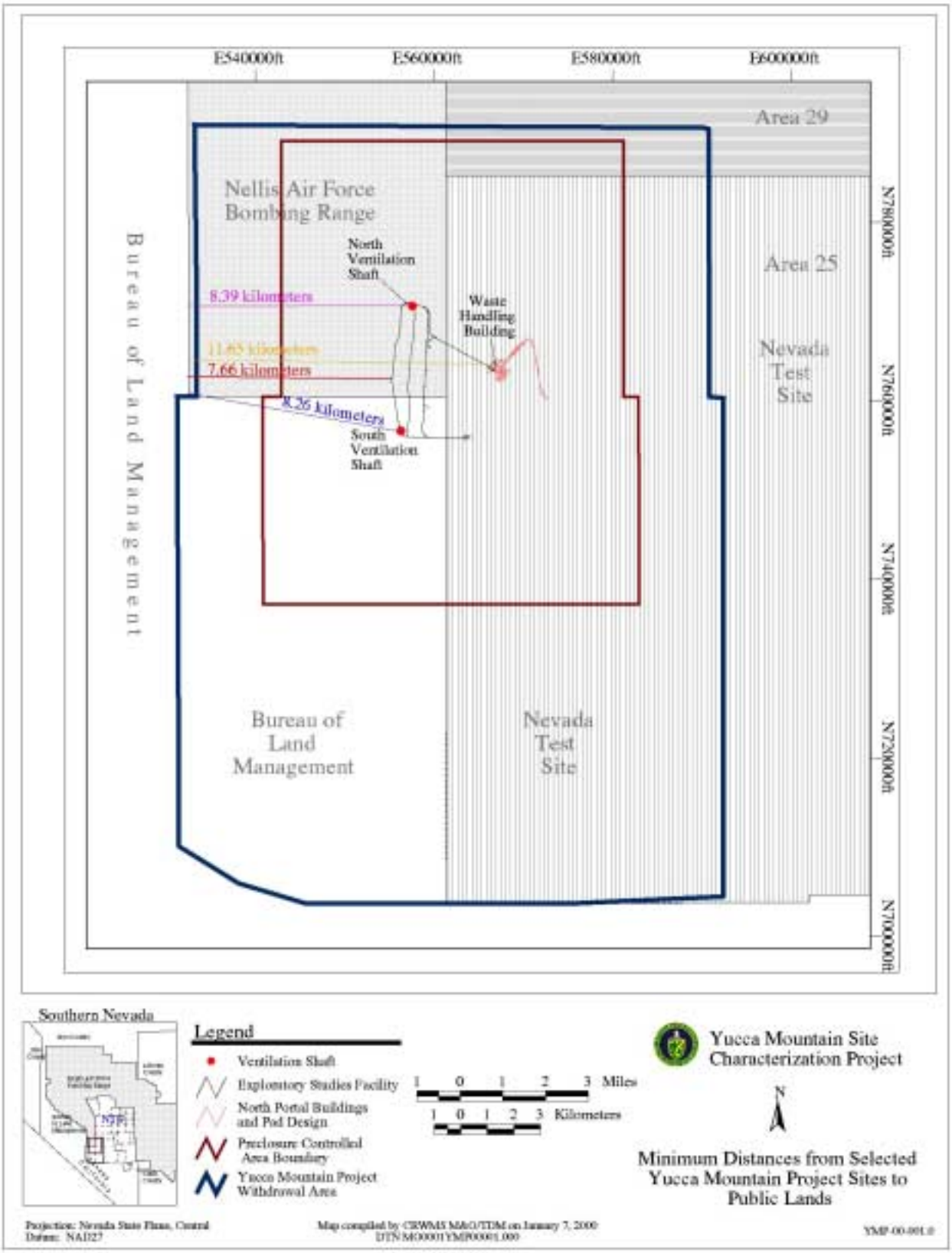
Attachment II

Acronyms and Abbreviations

AED	Aerodynamic Equivalent Diameter
AP	Administrative Procedure
ARF	Airborne Release Fraction
ATS	Assembly Transfer System
BWR	Boiling Water Reactor
CDE	Committed Dose Equivalent
CEDE	Committed Effective Dose Equivalent
CFR	Code of Federal Regulations
Ci	Curies
CSNF	Commercial Spent Nuclear Fuel
DBE	Design Basis Event
DC	Disposal Container
DCF	Dose Conversion Factor
DDE	Deep Dose Equivalent
DOE	U.S. Department of Energy
DF	Damage Fraction
EIS	Environmental Impact Statement
f_1	Fractional Uptake from the Small Intestines to Blood
FA	Fuel Assembly
GWd	Gigawatt Days
H-3	Hydrogen-3 (tritium gas)
HEP	Human Error Probability
HEPA	High-Efficiency Particulate Air
HVAC	Heating, Ventilation and Air-Conditioning
ICRP	International Commission on Radiological Protection
Kr-85	Krypton-85 (gas)
MGR	Monitored Geologic Repository
MOX	Mixed Oxide
mrem	Millirem
MTU	Metric Tons Uranium
NRC	U.S. Nuclear Regulatory Commission
PWR	Pressurized Water Reactor
RF	Respirable Fraction
SEC	Single Element Canister
SFA	Spent Fuel Assembly
SNF	Spent Nuclear Fuel
SSC	Structure, System or Component
SUNS	Sensitivity and Uncertainty Analysis Shell
TBD	To Be Determined
TEDE	Total Effective Dose Equivalent
VA	Viability Assessment
WHB	Waste Handling Building
WP	Waste Package

Attachment III

Proposed YMP Withdrawal Area Boundary


E540000ft
E560000ft
E580000ft
E600000ft
N780000ft
N760000ft
N740000ft
N720000ft
N700000ft
Area 29
Nellis Air Force Bombing Range
Area 25
Nevada Test Site
Bureau of Land Management
North Ventilation Shaft
Waste Handling Building
8.39 kilometers
11.65 kilometers
7.66 kilometers
8.26 kilometers
South Ventilation Shaft
Bureau of Land Management
Nevada Test Site
Southern Nevada
Legend
Ventilation Shaft
Exploratory Studies Facility
North Portal Buildings and Pad Design
Preclosure Controlled Area Boundary
Yucca Mountain Project Withdrawal Area
1 0 1 2 3 Miles
1 0 1 2 3 Kilometers
Yucca Mountain Site Characterization Project
N
Minimum Distances from Selected Yucca Mountain Project Sites to Public Lands
Projection: Nevada State Plane, Central
Datum: NAD27
Map compiled by CRWMS M&O/TDM on January 7, 2000
DTN M00001YMP00001.000
YMP-00-001.0

Attachment IV

GENII-S Dose Calculation Methodology for Category 1 Events

1. PURPOSE

This attachment describes the preclosure dose calculation methodology using the GENII-S computer code (CRWMS M&O 1998c) for chronic atmospheric releases of radionuclides from MGR surface and subsurface facilities during normal operations and from Category 1 design basis events (DBEs). This calculation was performed to support the Site Recommendation Preclosure Safety Assessment.

Continuous or routine releases of radioactive materials into the environment are term *chronic*. Routine releases during normal operations of MGR surface and subsurface facilities are expected. Releases from Category 1 DBEs postulated to occur in the Waste Handling Building (WHB) are treated as chronic releases. A chronic atmospheric release scenario involves prospective dose to individuals at specified distances and directions from the source via potential pathways, including submersion, inhalation, groundshine, and ingestion.

2. CALCULATION

Three Category 1 event scenarios are considered in the preclosure dose calculations: routine release from the WHB, routine release from emplacement drifts, and Category 1 DBE releases from the WHB. These scenarios involve chronic atmospheric releases of radionuclides in gaseous or particulate form from MGR surface and subsurface facilities. This calculation is based on the deterministic method using a mean or best estimate value for each GENII-S input parameter.

2.1 DESCRIPTION OF CATEGORY 1 RELEASES

2.1.1 Routine Release from Waste Handling Building

Kr-85 is the only radionuclide expected to be released from the surface facilities during normal operations. Shipping casks are transferred from the Carrier Bay to the Cask Preparation Pit, where the cask lid is removed. The cask is then transferred to the cask unloading pool where the fuel assemblies are transferred from the cask to the assembly staging rack. During normal operations, K-85 could be released from the shipping cask during the Assembly Transfer System (ATS) cask unloading operations. A Kr-85 emission rate of 4,010 Ci/yr was estimated based on average yearly throughputs of 3,873 PWR assemblies and 5,351 BWR assemblies passing through the ATS every year (CRWMS M&O 2000a).

Since Kr-85 is a gaseous radionuclide, no deposition of Kr-85 on the ground is considered. Therefore, there is no external exposure dose or ingestion dose due to contaminated soil. Only air submersion and inhalation doses are calculated. An atmospheric dispersion factor, χ/Q, of 1.99E-7 s/m^3 is used, which represents a chronic maximum sector χ/Q value at a distance of 11 km from the Waste Handling Building (WHB).

This scenario was analyzed using the GENII-S computer code. The GENII-S computer run for this scenario is named "PRCHSF". The source term for this scenario is given in Table 1 and other GENII-S input parameters are discussed in Section 2.2.

2.1.2 Routine Release from Emplacement Drifts

Neutrons leaked out of the emplaced waste packages during normal operations could activate ventilated airflow through subsurface emplacement drifts and the host rock surrounding the emplaced waste packages. The source of activated silica dust could come from air supply to emplacement drifts as well as the host rock around emplacement drifts. The activation products in air include N-16 and AR-41 and the airborne silica dust, which consists of N-16, Na-24, Al-28, Si-31, K-42, and Fe-55.

All these radionuclides have relatively short half-lives. Three radionuclides, N-16, Al-28, and K-42 can not be calculated using the GENII-S code, because they are not listed in the GENII-S radionuclide library and dose conversion factor input data files. All pathways are considered for this group based on chronic releases. Since none of these radionuclides are evaluated for food transfer factors, GENII-S default food transfer factor file, FTRANS.DAT, is used. A χ/Q of 2.98E-7 s/m^3 is used, which represents a chronic maximum sector value at a distance of 8 km from the nearest emplacement drift.

This scenario was analyzed using the GENII-S computer code. The GENII-S computer run for this scenario is named "PRCHSB". The source term for this computer run is given in Table 1 and other GENII-S input parameters are discussed in Section 2.2 of this Attachment.

2.1.3 Category 1 DBE Releases from Waste Handling Building

There are 17 Category 1 DBEs evaluated in Attachment VII of the calculation. The source term for each radionuclide from all 17 events is calculated in "SR Cat. 1 Release.xls", worksheet "Total Cat. 1 Release" (Attachment IX). Fifty-eight radionuclides are listed as important radionuclides for Category 1 DBE releases, and two radionuclides, Co-60 and Fe-55, are listed in both fuel fines and crud. The total release of Co-60 or Fe-55 is obtained by summing the curies from fuel fines and crud and hence only fifty-six radionuclides are considered. Four calculations are needed in order to separate gaseous releases from particulate releases, and to overcome the code limitation of 25 radionuclides for each run. In addition, in these four calculations different food transfer factor data files are used as discussed below. A χ/Q of 1.99E-7 s/m^3 is used for this scenario, which represents a chronic maximum sector value at a distance of 11 km from the WHB.

1. Gaseous radionuclides. Three radionuclides are in the group, including H-3, I-129, and Kr-85. As these three are considered as gaseous radionuclides, only air submersion and inhalation doses are calculated. The GENII-S computer run for this group of radionuclides is named "PRCHGS".

2. Particulate radionuclides without food transfer factor evaluation. Twenty-five radionuclides are in the group, including Cl-36, Fe-55, Co-60, Se-79, Zr-93, Nb-93m, Nb-94, Ru-106, Pd-107, Cd-103m, Sb-125, Sn-126, Pm-147, Sm-147, Sm-151, Eu-154, Eu-155, Pb-210, Ra-226, Ra228, Cm-242, Cm-243, Cm-244, Cm-245, and Cm-246. However, four radionuclides among them, Sm-147, Ra-226, Pb-210, and Ra-228, have zero annual release. Therefore,

only 21 radionuclides in this group are actually considered. GENII-S default food transfer factor file, FTRANS.DAT, is used. The GENII-S computer run for this group of radionuclides is named "PRCHP1".

3. Particulate radionuclides with food transfer factor directly evaluated. Nineteen radionuclides are in this group, including C-14, Ni-63, Sr-90, Tc-99, Cs-137, Ac-227, Th-229, Pa-231, U-232, U-233, U-234, U-236, U-238, Np-237, Pu-238, Pu-239, Pu-240, Am-241, and AM-243. However, one radionuclide, Th-229, has zero annual release. Thus, eighteen radionuclides in this group are actually considered. For this group, an updated food transfer factor file for reasonable representation, FTRANRR.TXT (Figure 1), is used. The GENII-S computer run for this group of radionuclides is named "PRCHP2".

4. Particulate radionuclides with transfer factor evaluated. Nine radionuclides are in this group, including Ni-59, Cs-134, Cs-135, Th-230, Th-232, U-235, Pu-241, Pu-242, and Am-242m. However, one radionuclide, Th-232, has zero annual release. Thus, eight radionuclides in this group are actually considered. For this group, an updated food transfer factor file for reasonable representation, FTRANRR.TXT (Figure 1), is used. The GENII-S computer run for this group of radionuclides is named "PRCHP3".

The source terms for computer runs PRCHGS, PRCHP1, PRCHP2, and PRCHP3 are given in Table 1.

Table 1. Source Terms for GENII-S Computer Runs

GENII-S Run	Radionuclide	Air Release (Ci/yr)
PRCHSF	Kr-85	4.01E+03
PRCHSB	Na-24	6.471E-03
	Si-31	7.17E-04
	Ar-41	5.728E+01
	Fe-55	1.492E-04
PRCHGS	H-3	1.46E+02
	Kr-85	1.45E+03
	I-129	2.82E-02
PRCHP1	Cl-36	3.39E-09
	Fe-55	7.72E-02
	Co-60	1.9656E-02
	Se-79	2.28E-08
	Zr-93	4.46E-07
	Nb-93m	6.49E-06
	Nb-94	4.19E-07
	Ru-106	6.14E-09
	Pd-107	4.20E-08
	Cd-113m	3.82E-06
	Sb-125	4.85E-06
	Sn-126	1.92E-07
	Pm-147	5.94E-05
	Sm-147	0
	Sm-151	1.05E-04
	Eu-154	3.35E-04

Table 1. Source Terms for GENII-S Computer Runs (continued)

GENII-S Run	Radionuclide	Air Release (Ci/yr)
PRCHP1 (continued)	Eu-155	2.57E-05
	Ra-226	0
	Pb-210	0
	Ra-228	0
	Cm-242	2.63E-06
	Cm-244	6.79E-04
	Cm-245	1.53E-07
	Cm-246	5.19E-08
	Cm-243	5.14E-06
PRCHP2	C-14	1.66E-07
	Ni-63	1.26E-04
	Sr-90	1.36E-02
	Tc-99	4.49E-06
	Cs-137	1.37E-01
	U-232	1.02E-08
	U-234	3.38E-07
	U-236	8.58E-08
	Pa-231	1.48E-11
	Ac-227	8.03E-12
	Np-237	1.23E-07
	U-233	2.03E-11
	Th-229	0
	U-238	7.39E-08
	Pu-238	1.14E-03
	Pu-240	1.59E-04
	Am-241	9.88E-04
	Am-243	1.1E-05
	Pu-239	8.83E-05
PRCHP3	Ni-59	1.04E-06
	Cs-134	8.38E-05
	Cs-135	1.16E-06
	Th-230	7.39E-11
	Th-232	0
	U-235	3.67E-09
	Am-242m	3.19E-06
	Pu-242	8.18E-07
	Pu-241	1.23E-02

2.2 GENII-S INPUT DATA FILES

The GENII-S input data are taken as the reasonable representation case from biosphere analysis model reports (AMRs), except for the receptor data, which includes food and water consumption rates, inhalation time, and external exposure time. These data are taken from those developed for the subsistence farmer in the Total System Performance Assessment (TSPA) for Viability Assessment (VA) (CRWMS M&O 1998a).

This calculation used subsistence farmer's food consumption rates as shown in Table 2. A subsistence farmer is defined as the maximally exposed individual of the critical group who grows all his/her own food using irrigation water from a well. All domestic water was assumed

to come from a well. Table 2 contains the best estimate consumption parameters for locally produced food (CRWMS M&O 1998a) used for food consumption rates for this calculation.

Table 2. Consumption Parameters for Locally-Produced Food for the Subsistence Farmer.

Food Type[1]	Best Estimate
Leafy Vegetables (kg/yr)	63.55
Root Vegetables (kg/yr)	28.86
Grains (kg/yr)	60.64
Fruit (kg/yr)	59.32
Poultry (kg/yr)	15.74
Meat[2] (kg/yr)	38.97
Eggs (kg/yr)	16.67
Milk (l/yr)	136.0
Tap Water[3] (l/yr)	867.7

[1] The specific food types shown are those used in the biosphere analysis completed for Total System Performance Assessment/Viability Assessment.

[2] "Meat" is comprised of beef and pork.

[3] This refers to water from a local ground source. It excludes any bottled water purchased form a commercial vendor.

An individual lives in the vicinity of Yucca Mountain and draws untreated ground water for drinking water supply. This individual also uses the ground water to irrigate crops and lawns and raise livestock. It is assumed that the groundwater is not contaminated during the preclosure period. Consequently, this individual will not be exposed to radiation resulting from ingestion of ground water. However, this individual will consume locally produced food; inhalation of resuspended dust; and direct external exposure to contaminated soil. The calculated dose is the Total Effective Dose Equivalent, or TEDE (rem/yr). The TEDE is defined as the sum of the deep-dose equivalent (for external exposures) and the 50-year committed effective dose equivalent (for internal exposures) (10 CFR 20).

The GENII-S input parameters for this calculation are based on output data from the TSPA-VA (CRWMS M&O 1998a) and the six Data Tracking Numbers (DTNs) shown below:

- MO0003RIB00061.001. *Input Parameter Values for External and Inhalation Radiation Exposure Analysis*.
- MO9911RIB00064.000. *Environmental Transport Parameter Values for Dose Assessment*.
- MO9911RIB00065.000. *Parameter Values for Transfer Coefficients*.
- MO9912RIB00066.000. *Parameter Values for Internal and External Dose Conversion Factors*.
- MO9912SPAING06.033. *Ingestion Exposure Pathway Parameters*.
- SN0002T0512299.003. *Revised Leaching Coefficients for GENII-S Code*.

Data can be entered into GENII-S software through a series of interactive data input screens and by modifying input data files located in GENII-S directory. Table 3 lists all the input data that must be entered into GENII-S through the data input screens. The table is constructed so that it closely represents the actual data input screens in the software.

Table 3. GENII-S Input Parameters for Preclosure Dose Calculations

Parameter	Best Estimate	Comments
Fixed Data Group 1: Population /Soil/Scenario Data		
Total Population (0=Use POP.IN)	1	ANL-MGR-MD-000009 Rev 00 (CRWMS M&O 2000c)
Population Scale Factor	1	ANL-MGR-MD-000009 Rev 00 (CRWMS M&O 2000c)
Dose Commitment Period (yr)	50	10 CFR 20
Surface Soil Depth (cm)	15	DTN: MO9911RIB00064.000
Surface Soil Density (kg/m^2)	225	DTN: MO9911RIB00064.000
Deep Soil Density (kg/m^3)	1500	N/A
Roots in Upper Soil (Fraction)	1	DTN: MO9911RIB00064.000
Roots in Deep Soil (Fraction)	0	N/A
Air Rel. Time Before Intake (yr)	0	N/A
H_20 Rel. Time Before Intake (yr)	0	N/A
Fixed Data Group 2: Air Transport Data		
Air Release Duration (yr)	1	1 = Annual Dose
Air release Prior to Intake (yr)	0	Dose begins at t=0
Air dispersion Option (0-3)	1	1 = user input χ/Q
Chi/Q Value (s/m^3)	2.98E-07 /1.99E-07	TDR-MGR-MM-000001 Rev 00 (CRWMS M&O 1999c)
Sector (direction) Index (1-16)	16	TDR-MGR-MM-000001 Rev 00 (CRWMS M&O 1999c)
Distance from Release (m)	8,000 /11,000	TDR-MGR-MM-000001 Rev 00 (CRWMS M&O 1999c)
Joint Frequency Data Flag (0/1=N/Y)	0	N/A
Stack release Flag (0-3)	0	N/A
Plume Rise Flag (0/1=N/Y)	0	N/A
Stack Height (m)	0	N/A
Stack Flow Rate (m^3/s)	0	N/A
Stack Radius (m)	0	N/A
Effluent Temperature (Deg. C)	0	N/A
Building X-Sect Area (m^2)	0	N/A
Building height (m)	0	N/A
Fixed Data Group 3: External /Inhalation Exposure		
Chronic Plume Exposure (hr)	6192	TSPA VA Critical Group (CRWMS M&O 1998a)
Acute Plume Exposure (hr/phr)	0	N/A
Inhalation Exposure (hr/yr)	6192	TSPA VA Critical Group (CRWMS M&O 1998a)
Resupension Model Flag (0-2)	1	1 = Mass Loading Method
Mass Load(g/m^3);Soil Depth (cm)	8.7E-06	50% value; DTN: MO0003RIB00061.001
Transit Time to Rec. Site (hr)	0	N/A
Swimming Exposure Time (hr)	0	N/A
Boating Exposure Time (hr)	0	N/A
Shoreline Exposure Time (hr)	0	N/A
Type of Shoreline Index (1-4)	0	N/A
H_2O/Sed. Transfer ($l/m^2/yr$)	0	N/A
Soil Exposure Time (hr)	3624	TSPA VA Critical Group (CRWMS M&O 1998a)
Home Irrigation Flag (0/1=N/Y)	0	0 = Residential soils not irrigated
Irrigation Water Index (1-2)	0	N/A
Home Irrigation Rate (in/yr)	69.5	N/A
Home Irrigation Duration (mo/yr)	12	N/A
Fixed Data Group 4: Ingestion Exposure		
Food Production Option (0-3)	1	1 = χ/Q multiplied by POP.IN
Food-Weighted Chi/Q ($kg-s/m^3$)	0	N/A
Crop Resupension Factor (1/m)	8.3E-11	DTN: MO9911RIB00064.000
Crop Desposition Velocity (m/s)	0.001	DTN: MO9911RIB00064.000

Table 3. GENII-S Input Parameters for Preclosure Dose Calculations (continued)

Parameter	Best Estimate	Comments
Crop Interception Fraction (-)	0.259	DTN: MO9911RIB00064.000
Exported Food Dose (0/1=N/Y)	0	ANL-MGR-MD-000009 Rev 00 (CRWMS M&O 2000c)
Soil Ingestion Rate (mg/day)	50	DTN: MO9911RIB00064.000
Swim H_2O Ingestion Rate (l/hr)	0	N/A
Population Ingesting Aquatic Food	0	N/A
Bioaccumulation Flag (0/1=N/Y)	0	0 = fresh water
Population Drinking Contaminated Water	1	ANL-MGR-MD-000009 Rev 00 (CRWMS M&O 2000c)
Drink Water Source Index (0-3)	0	0 = Drinking water not contaminated
Drink Water Treated (0/1=N/Y)	0	ANL-MGR-MD-000009 Rev 00 (CRWMS M&O 2000c)
Drink Water Holdup Time (days)	0	ANL-MGR-MD-000009 Rev 00 (CRWMS M&O 2000c)
Drink Water Consumption (l/yr)	867.7	Table 2
Array Number 1: Aquatic Food Ingestion		
Fish Transit Time (hr)	0	N/A
Mollusc Transit Time(hr)	0	N/A
Crustacea Transit Time (hr)	0	N/A
Plants Transit Time(hr)	0	N/A
Fish Production (kg/yr)	0	N/A
Mollusc Production (kg/yr)	0	N/A
Crustacea Production (kg/yr)	0	N/A
Plants Production (kg/yr)	0	N/A
Fish Holdup (days)	0	N/A
Mollusc Holdup (days)	0	N/A
Crustacea Holdup (days)	0	N/A
Plants Holdup (days)	0	N/A
Fish Consumption (kg/yr)	0	N/A
Mollusc Consumption (kg/yr)	0	N/A
Crustacea Consumption (kg/yr)	0	N/A
Plants Consumption (kg/yr)	0	N/A
Array Number 2: Terrestrial Food Ingestion		
Water Source (0-2)	0	0 = Contaminated water not used to irrigate
Leaf Vegetable Grow Time (days)	64.5	(Min+Max)/2, DTN: MO9912SPAING06.033
Root Vegetable Grow Time (days)	84	(Min+Max)/2, DTN: MO9912SPAING06.033
Fruit Grow Time (days)	136	(Min+Max)/2, DTN: MO9912SPAING06.033
Grain Grow Time (days)	159.5	(Min+Max)/2, DTN: MO9912SPAING06.033
Leaf Vegetable Irrigation Rate (in/yr)	42.11	(Min+Max)/2, DTN: MO9912SPAING06.033
Root Vegetable Irrigation Rate (in/yr)	49.46	(Min+Max)/2, DTN: MO9912SPAING06.033
Fruit Irrigation Rate (in/yr)	37.685	(Min+Max)/2, DTN: MO9912SPAING06.033
Grain Irrigation Rate (in/yr)	68.11	(Min+Max)/2, DTN: MO9912SPAING06.033
Leaf Vegetable Irrigation Time (mo/yr)	3.2	(Min+Max)/2, DTN: MO9912SPAING06.033
Root Vegetable Irrigation Time (mo/yr)	3.9	(Min+Max)/2, DTN: MO9912SPAING06.033
Fruit Irrigation Time (mo/yr)	4.45	(Min+Max)/2, DTN: MO9912SPAING06.033
Grain Irrigation Time (mo/yr)	6.45	(Min+Max)/2, DTN: MO9912SPAING06.033
Leaf Vegetable Yield (kg/m^2)	1.82	(Min+Max)/2, DTN: MO9912SPAING06.033
Root Vegetable Yield (kg/m^2)	4.33	(Min+Max)/2, DTN: MO9912SPAING06.033
Fruit Yield (kg/m^2)	1.91	(Min+Max)/2, DTN: MO9912SPAING06.033
Grain Yield (kg/m^2)	.555	(Min+Max)/2, DTN: MO9912SPAING06.033
Leaf Vegetable Production (kg/yr)	0	N/A
Root Vegetable Production (kg/yr)	0	N/A
Fruit Production (kg/yr)	0	N/A
Grain Production (kg/yr)	0	N/A
Leaf Vegetable Holdup (days)	1	DTN: MO9912SPAING06.033
Root Vegetable Holdup (days)	14	DTN: MO9912SPAING06.033
Fruit Holdup (days)	14	DTN: MO9912SPAING06.033
Grain Holdup (days)	14	DTN: MO9912SPAING06.033
Leaf Vegetable Consumption (kg/yr)	63.55	Table 2

Table 3. GENII-S Input Parameters for Preclosure Dose Calculations (continued)

Parameter	Best Estimate	Comments
Root Vegetable Consumption (kg/yr)	28.86	Table 2
Fruit Consumption (kg/yr)	59.32	Table 2
Grain Consumption (kg/yr)	60.64	Table 2
Array Number 2: Terrestrial Food Ingestion		
Water Source (0-2)	0	0 = No contaminated water
Beef Consumption Rate (kg/yr)	38.97	Table 2
Poultry Consumption Rate (kg/yr)	15.74	Table 2
Milk Consumption (l/yr)	136	Table 2
Eggs Consumption Rate (kg/yr)	16.67	Table 2
Beef Holdup (days)	20	MO9912SPAING06.033
Poultry Holdup (days)	1	MO9912SPAING06.033
Milk Holdup (days)	1	MO9912SPAING06.033
Eggs Holdup (days)	1	MO9912SPAING06.033
Beef Production (kg/yr)	0	N/A
Poultry Production (kg/yr)	0	N/A
Milk Production (kg/yr)	0	N/A
Eggs Production (kg/yr)	0	N/A
Beef-Water Fraction	0	0 = No contaminated water
Poultry-Water Fraction	0	0 = No contaminated water
Milk-Water Fraction	0	0 = No contaminated water
Eggs-Water Fraction	0	0 = No contaminated water
Beef-Diet Fraction	0	DTN: MO9912SPAING06.033
Poultry-Diet Fraction	1	DTN: MO9912SPAING06.033
Milk-Diet Fraction	0	DTN: MO9912SPAING06.033
Eggs-Diet Fraction	1	DTN: MO9912SPAING06.033
Beef-Grow Time (days)	0	N/A
Poultry-Grow Time (days)	75	DTN: MO9912SPAING06.033
Milk-Grow Time (days)	0	N/A
Eggs-Grow Time (days)	75	DTN: MO9912SPAING06.033
Beef-Irrigation Rate (in/yr)	0	N/A
Poultry-Irrigation Rate (in/yr)	80.37	DTN: MO9912SPAING06.033
Milk-Irrigation Rate (in/yr)	0	N/A
Eggs-Irrigation Rate (in/yr)	80.37	DTN: MO9912SPAING06.033
Beef-Irrigation Time (mo/yr)	0	N/A
Poultry-Irrigation Time (mo/yr)	4.9	DTN: MO9912SPAING06.033
Milk-Irrigation Time (mo/yr)	0	N/A
Eggs-Irrigation Time (mo/yr)	4.9	DTN: MO9912SPAING06.033
Beef-Feed Yield (kg/m^2)	0	N/A
Poultry-Feed Yield (kg/m^2)	0.685	(Min+Max)/2, DTN: MO9912SPAING06.033
Milk-Feed Yield (kg/m^2)	0	N/A
Eggs-Feed Yield (kg/m^2)	0.685	(Min+Max)/2, DTN: MO9912SPAING06.033
Beef-Storage (days)	0	N/A
Poultry-Storage (days)	14	DTN: MO9912SPAING06.033
Milk-Storage (days)	0	N/A
Eggs-Storage (days)	14	DTN: MO9912SPAING06.033
Array Number 4: Animal Products (Fresh Forage)		
Water Source Flag (0-2)	0	0 = Contaminated water not used to irrigate
Beef-Diet Fraction	1	DTN: MO9912SPAING06.033
Milk-Diet Fraction	1	DTN: MO9912SPAING06.033
Beef-Grow Time (days)	47	DTN: MO9912SPAING06.033
Milk-Grow Time (days)	47	DTN: MO9912SPAING06.033
Beef-Irrigation Rate (in/yr)	94.66	DTN: MO9912SPAING06.033
Milk-Irrigation Rate (in/yr)	94.66	DTN: MO9912SPAING06.033
Beef-Irrigation Time (mo/yr)	12	DTN: MO9912SPAING06.033
Milk-Irrigation Time (mo/yr)	12	DTN: MO9912SPAING06.033
Beef-Feed Yield (kg/m^2)	0.7	(Min+Max)/2, DTN: MO9912SPAING06.033

Table 3. GENII-S Input Parameters for Preclosure Dose Calculations (continued)

Parameter	Best Estimate	Comments
Milk-Feed Yield (kg/m^2)	0.7	(Min+Max)/2, DTN: MO9912SPAING06.033
Beef-Feed Storage Time (days)	0	N/A
Milk-Feed Storage Time (days)	0	N/A
Array Number 5: Inventory-Release Terms		
Radionuclides in Air (Ci/yr)	Variable	Varies for each run

Three data files in GENII-S were modified to accommodate the results of site-specific studies on the GENII-S input parameters. The original names of these three files are FTRANS.DAT, DEFAULT.IN, and GRDF.DAT.

FTRANS.DAT is the default GENII-S food transfer and soil leaching factor library. The soil leaching factors are important parameters for determining radionuclide buildup in soil. The food transfer factors relate concentrations of elements in soil to concentrations in farm products grown in that soil and concentrations in animal feed to concentrations in animal products. FTRANS.DAT, was used in computer runs, PRCHSF, PRCHGS, and PRCHP1. An updated FTRANS.DAT, renamed as FTRANRR.TXT was developed and used in computer runs PRCHP2 and PRCHP3. The FTRANRR.TXT parameters are illustrated in Figure 1.

Figure 1. List of FTRANRR.TXT File

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Food Transfer Factors for Reasonable Representation (8/30/99)
Ele- Dep Vel Leafy   Root    Fruit   Grain   Beef   Poulty  Milk    Egg     Leaching
men   m/sec  Veg     Veg      --      --     day/kg day/kg  day/L   day/kg  Factor
AC   1.0E-3  3.5E-3  3.5E-4  3.5E-4  3.5E-4 2.5E-5  4.0E-3  2.0E-5  2.0E-3  1.5E-03
AM   1.0E-3  2.0E-3  4.7E-4  4.1E-4  9.0E-5 2.0E-5  6.0E-3  2.0E-6  4.0E-3  3.6E-04
BI   1.0E-3  6.0E-1  6.0E-1  6.0E-1  6.0E-1 1.7E-2  9.9E-4  5.0E-4  9.9E-4  2.7E-05
C    0.0E+0  0.0E+0  0.0E+0  0.0E+0  0.0E+0 0.0E+0  0.0E+0  0.0E+0  0.0E+0  2.4E-04
CS   1.0E-3  1.3E-1  4.9E-2  2.2E-1  2.6E-2 5.0E-2  4.4E+0  8.0E-3  4.0E-1  2.4E-04
I    1.0E-2  3.4E-3  5.0E-2  5.0E-2  5.0E-2 7.0E-3  1.8E-2  1.0E-2  3.0E+0  5.9E-01
MO   1.0E-3  2.5E-1  6.0E-2  6.0E-2  6.0E-2 1.0E-3  1.9E-1  1.5E-3  9.0E-1  6.7E-02
NI   1.0E-3  2.8E-1  6.0E-2  6.0E-2  3.0E-2 5.0E-3  1.0E-3  1.6E-2  1.0E-1  1.7E-03
NP   1.0E-3  3.7E-2  1.7E-2  1.7E-2  2.7E-3 1.0E-3  4.0E-3  5.0E-6  2.0E-3  1.3E-01
PA   1.0E-3  2.5E-3  2.5E-4  2.5E-4  2.5E-4 5.0E-5  4.0E-3  5.0E-6  2.0E-3  1.1E-01
PB   1.0E-3  1.0E-1  1.0E-1  1.0E-1  1.0E-2 4.0E-4  9.9E-4  3.0E-5  9.9E-4  4.5E-04
PO   1.0E-3  1.0E-2  1.0E-2  1.0E-2  1.0E-3 4.5E-3  9.9E-4  1.2E-4  9.9E-4  2.7E-05
PU   1.0E-3  4.0E-4  2.0E-4  1.9E-4  2.6E-5 1.0E-5  3.0E-3  1.1E-6  8.0E-3  1.2E-03
RA   1.0E-3  8.0E-2  1.3E-2  6.1E-3  1.2E-3 9.0E-4  3.0E-2  1.3E-3  2.0E-5  1.4E-03
SR   1.0E-3  2.0E+0  1.2E+0  2.0E-1  2.0E-1 8.0E-3  8.0E-2  1.5E-3  3.0E-1  3.4E-02
TC   1.0E-3  4.0E+1  1.5E+0  1.5E+0  7.3E-1 1.0E-4  3.0E-2  1.0E-2  3.0E+0  2.8E+00
TH   1.0E-3  4.0E-3  3.0E-4  2.1E-4  3.4E-5 1.0E-4  4.0E-3  5.0E-6  2.0E-3  2.1E-04
U    1.0E-3  8.5E-3  1.4E-2  4.0E-3  1.3E-3 3.0E-4  1.2E+0  6.0E-4  1.0E+0  1.9E-02
Y    1.0E-3  1.5E-2  6.0E-3  6.0E-3  6.0E-3 1.0E-3  1.0E-2  2.0E-5  2.0E-3  4.0E-03
```

The soil leaching factors shown in Figure 1, based on DTN: SN9912T0512299.001, were revised shortly after Revision 00 of this calculation was issued. These leaching factors were superseded by the revised best estimate soil leaching factors in DTN: SN0002T0512299.003. The revised leaching factors, shown in Table 4, are less conservative (i.e., larger values) than the original soil leaching factors for every element except Palladium (Pa). However, the dose contribution from Palladium is negligible. Therefore, the calculated dose results from Revision 00 are conservative and still valid. As a result, no additional calculations were deemed necessary.

Table 4. Original Versus Revised Soil Leaching Factors

	Best Estimate Leaching Coefficient (yr^{-1})	
Element	Original (DTN: SN9912T0512299.001)	Revised (DTN: SN0002T0512299.003)
Ac	1.5E-03	1.5E-03
Am	3.6E-04	3.56E-04
Bi	2.7E-05	6.76E-03
C	2.4E-04	1.32E-01
Cs	2.4E-04	2.42E-03
I	5.9E-01	5.92E-01
Mo	6.7E-02	6.68E-02
Ni	1.7E-03	1.69E-03
Np	1.3E-01	1.32E-01
Pa	1.1E-01	1.23E-03
Pb	4.5E-04	2.51E-03
Po	2.7E-05	4.51E-03
Pu	1.2E-03	1.23E-03
Ra	1.4E-03	1.35E-03
Sr	3.4E-02	4.47E-02
Tc	2.8E+00	2.77E+00
Th	2.1E-04	2.12E-04
U	1.9E-02	1.93E-02
Y	4.0E-03	3.98E-03

DEFAULT.IN is a file containing default values for various parameters needed in a GENII-S calculation. This file is always required to run GENII-S. The default values in this file can be changed by using an external text editor. Figure 2 lists the modified DEFAULT.IN, which is renamed as DEF_RR.TXT, a default file for reasonable representation using the results from previous biosphere AMRs. The data in the DEF_RR.TXT file are compiled from input data contained in DTN numbers MO9911RIB00064.000, MO9912RIB00066.000, and MO9912SPAING06.033.

External dose coefficients for air submersion, water surface, soil surface, deep soil, and buried waste for different radionuclides are given in the GENII-S default file GRDF.DAT. This file was replaced by GRDF.15, which is based on Federal Guidance Report 12 (Eckerman and Ryman 1993) dose coefficients for air submersion and external exposure to soil contaminated to a depth of 15 cm. The file GRDF.15 is listed in Figure 3.

The worst case solubility internal dose conversion factors are used for inhalation and ingestion calculations. These DCFs are based on the updated GENII-S binary file DOSINC.DAT. This file was compared with Federal Guidance Report 11 (Eckerman et al. 1988) in DTN: MO9912RIB00066.000, which recommended that it be used for radionuclides evaluated in postclosure biosphere modeling.

Figure 2. List of DEF_RR.TXT File

```
GENII Default Parameters for Reasonable Representation Cases (30-Aug-99)

INVENTORY PARAMETERS-----------------------------------------------------
0.037, 3.7E4, 3.7E7, 3.7E10, 1.0          NVU     Source input conversion
1.0, 0.15, 225.0                          SVU     Soil source conversion
ENVIRONMENTAL PARAMETERS-------------------------------------------------
0.008                                     ABSHUM  Absolute humidity (kg/m3)
2                                         PRCNTI  Air dispersion conserv. flag
0.001                                     DPVRES  Deposition vel./resuspension
8.3E-11                                   LEAFRS  Leaf resuspension factor
2.0,2.0,3.0,0.8,0.8,0.8,1.0,0.8,1.0,1.5   BIOMAS  BIOMA2 Biomass (kg/m2)
0.259                                     DEPFR2  Interception frac./irrigate
15.0                                      SURCM   Depth of surface soil (cm)
225.0                                     SLDN    Surface soil density (kg/m2)
1.5E3                                     SSLDN   Soil density (kg/m3)
True                                      HARVST  Harvest removal considered?
50.0                                      SOLING  Soil ingested (mg/da)
14.0                                      WTIM    Weathering time (da)
1.0, 0.1, 0.1, 0.1                        TRANS   Translocation, plants
0.1, 0.1, 0.1, 0.1, 1.0, 1.0              TRANSA  Translocation, animal food
68.0, 0.12, 55.0, 0.12, 68.0, 55.0        CONSUM  Animal Consumption (kg/da)
50.0, 0.3, 60., 0.3                       DWATER  Animal drinking water (L/da)
0.0, 0.8, 1.0, 0.8                        FRACUT  Acute fresh forage by season
0.2, 0.3, 0.5, 1.0                        SHORWI  Shore width factors
0.02                                      INGWAT  Swim water ingested (L/hr)
25295.0                                   TCWS    H2O/sed. transfer (L/m2/yr)
0.4,  5.0, 4.0                            YELDBT  BIOT: Veg. prod. (kg/m2/yr)
9.41E-4, 2*7.48E-4                        TOTEXC  BIOT: Excavation (m2/m3-yr)
1.0, 0.81, 0.19, 0.02, 0.008, 0.002,      EXCAV   BIOT: Frac. soil brought to
1.0, 0.9, 0.096, 0.006, 0.0005, 0.0005,           surface from within the
1.0, 0.9, 0.096, 0.006, 0.0005, 0.0005            waste by animal excavation
266.2                                     RINH    Chronic breathing (cm3/sec)
330.0                                     RINHA   Acute breathing (cm3/sec)
10                                        NDIST   Number of distances
805.0, 2414.0, 4023.0, 5632.0, 7241.0,
12068.0, 24135.0, 40255.0, 56315.0,
72405.0                                   X       JF/chi/Q/pop grid dist. (m)
0.1, 0.25, 0.18, 0.91, 0.18, 0.91, 0.18,
0.91, 2*0.2                               DRYFAC, DRYFA2 dry/wet ratio
METABOLIC PARAMETERS-----------------------------------------------------
0.5, 50.0, 500.0                                  XDIV
0.5,  0.5,  0.95, 0.05,  0.8, 0.0, 0.0,   0.2, 0.0,     ADJ
0.1,  0.9,  0.5,  0.5,  0.15, 0.4, 0.4,  0.05, 0.0,
0.01, 0.99, 0.01, 0.99, 0.05, 0.4, 0.4, 0.135, 0.015

DOSE PARAMETERS----------------------------------------------------------
0.25, 0.15, 0.12, 0.12, 0.03, 0.03, 5*0.06        WT   Weighting factors
2.0                                               SI2I Semi-infinite/inf
```

Figure 3. List of GRDF.15 File

FGR12 air,water,soil(15 CM) DCFs (Sv/yr per Bq/n) (7 Aug 96 MAH)

nuclide	Air Submersion m3	Water Surface L	Soil 15 cm "m3"	Buried 0.15 m m3	Buried 0.5 m m3	Buried 1.0m m3
H 3	1.04E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BE7	7.44E-08	8.12E-08	4.42E-11	0.00E+00	0.00E+00	0.00E+00
BE10	3.53E-10	3.42E-10	1.79E-13	0.00E+00	0.00E+00	0.00E+00
C 14	7.06E-12	6.92E-12	2.27E-15	0.00E+00	0.00E+00	0.00E+00
N 13	1.55E-06	1.69E-06	9.18E-10	0.00E+00	0.00E+00	0.00E+00
F 18	1.55E-06	1.69E-06	9.21E-10	0.00E+00	0.00E+00	0.00E+00
NA22	3.41E-06	3.71E-06	1.99E-09	0.00E+00	0.00E+00	0.00E+00
NA24	6.87E-06	7.46E-06	3.75E-09	0.00E+00	0.00E+00	0.00E+00
SI31	3.69E-09	3.72E-09	2.17E-12	0.00E+00	0.00E+00	0.00E+00
P 32	3.12E-09	3.00E-09	1.89E-12	0.00E+00	0.00E+00	0.00E+00
P 33	2.60E-11	2.52E-11	9.97E-15	0.00E+00	0.00E+00	0.00E+00
S 35	7.66E-12	7.47E-12	2.51E-15	0.00E+00	0.00E+00	0.00E+00
CL36	7.03E-10	7.06E-10	3.85E-13	0.00E+00	0.00E+00	0.00E+00
K 40	2.54E-07	2.74E-07	1.44E-10	0.00E+00	0.00E+00	0.00E+00
AR39	2.87E-10	2.78E-10	1.43E-13	0.00E+00	0.00E+00	0.00E+00
AR41	2.05E-06	2.22E-06	1.17E-09	0.00E+00	0.00E+00	0.00E+00
CA41	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CA45	2.72E-11	2.65E-11	1.06E-14	0.00E+00	0.00E+00	0.00E+00
SC46	3.15E-06	3.41E-06	1.83E-09	0.00E+00	0.00E+00	0.00E+00
CR51	4.76E-08	5.20E-08	2.76E-11	0.00E+00	0.00E+00	0.00E+00
MN54	1.29E-06	1.40E-06	7.57E-10	0.00E+00	0.00E+00	0.00E+00
MN56	2.72E-06	2.93E-06	1.55E-09	0.00E+00	0.00E+00	0.00E+00
FE55	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FE59	1.88E-06	2.03E-06	1.08E-09	0.00E+00	0.00E+00	0.00E+00
CO57	1.77E-07	1.97E-07	8.39E-11	0.00E+00	0.00E+00	0.00E+00
CO58	1.50E-06	1.62E-06	8.83E-10	0.00E+00	0.00E+00	0.00E+00
CO60	3.97E-06	4.32E-06	2.29E-09	0.00E+00	0.00E+00	0.00E+00
NI59	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NI63	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NI65	8.80E-07	9.52E-07	5.01E-10	0.00E+00	0.00E+00	0.00E+00
CU64	2.87E-07	3.12E-07	1.71E-10	0.00E+00	0.00E+00	0.00E+00
ZN65	9.15E-07	9.92E-07	5.30E-10	0.00E+00	0.00E+00	0.00E+00
ZN69M	6.28E-07	6.84E-07	3.72E-10	0.00E+00	0.00E+00	0.00E+00
ZN69	6.81E-10	6.56E-10	3.72E-13	0.00E+00	0.00E+00	0.00E+00
GA72	4.38E-06	4.73E-06	2.47E-09	0.00E+00	0.00E+00	0.00E+00
AS76	6.72E-07	7.28E-07	3.94E-10	0.00E+00	0.00E+00	0.00E+00
SE75	5.83E-07	6.42E-07	3.19E-10	0.00E+00	0.00E+00	0.00E+00
SE79	9.56E-12	9.35E-12	3.14E-15	0.00E+00	0.00E+00	0.00E+00
BR82	4.10E-06	4.45E-06	2.40E-09	0.00E+00	0.00E+00	0.00E+00
BR83	1.20E-08	1.30E-08	7.13E-12	0.00E+00	0.00E+00	0.00E+00
KR83M	4.73E-11	5.50E-11	5.11E-15	0.00E+00	0.00E+00	0.00E+00
BR84	2.97E-06	3.22E-06	1.63E-09	0.00E+00	0.00E+00	0.00E+00
KR85M	2.36E-07	2.60E-07	1.24E-10	0.00E+00	0.00E+00	0.00E+00
KR85	3.75E-09	4.02E-09	2.20E-12	0.00E+00	0.00E+00	0.00E+00
KR87	1.30E-06	1.41E-06	7.25E-10	0.00E+00	0.00E+00	0.00E+00
RB87	5.74E-11	5.58E-11	2.37E-14	0.00E+00	0.00E+00	0.00E+00
KR88	3.22E-06	3.48E-06	1.78E-09	0.00E+00	0.00E+00	0.00E+00
RB88	1.06E-06	1.14E-06	5.96E-10	0.00E+00	0.00E+00	0.00E+00
KR89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RB89	3.34E-06	3.63E-06	1.89E-09	0.00E+00	0.00E+00	0.00E+00
SR89	2.44E-09	2.35E-09	1.46E-12	0.00E+00	0.00E+00	0.00E+00

Figure 3. List of GRDF.15 File (continued)

FGR12 air,water,soil(15 CM) DCFs (Sv/yr per Bq/n) (7 Aug 96 MAH)

nuclide	Air Submersion m3	Water Surface L	Soil 15 cm "m3"	Buried 0.15 m m3	Buried 0.5 m m3	Buried 1.0m m3
KR90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RB90M	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RB90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SR90	2.37E-10	2.30E-10	1.17E-13	0.00E+00	0.00E+00	0.00E+00
Y 90	5.99E-09	5.72E-09	3.78E-12	0.00E+00	0.00E+00	0.00E+00
SR87M	4.79E-07	5.25E-07	2.83E-10	0.00E+00	0.00E+00	0.00E+00
RB86	1.52E-07	1.64E-07	8.80E-11	0.00E+00	0.00E+00	0.00E+00
SR85	7.63E-07	8.29E-07	4.54E-10	0.00E+00	0.00E+00	0.00E+00
SR91	1.09E-06	1.18E-06	6.37E-10	0.00E+00	0.00E+00	0.00E+00
Y 91M	8.04E-07	8.74E-07	4.79E-10	0.00E+00	0.00E+00	0.00E+00
Y 91	8.20E-09	8.58E-09	4.79E-12	0.00E+00	0.00E+00	0.00E+00
SR92	2.14E-06	2.32E-06	1.22E-09	0.00E+00	0.00E+00	0.00E+00
Y 92	4.10E-07	4.43E-07	2.39E-10	0.00E+00	0.00E+00	0.00E+00
Y 93	1.51E-07	1.62E-07	8.64E-11	0.00E+00	0.00E+00	0.00E+00
MO93	7.95E-10	9.33E-10	9.97E-14	0.00E+00	0.00E+00	0.00E+00
ZR93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NB93M	1.40E-10	1.64E-10	1.76E-14	0.00E+00	0.00E+00	0.00E+00
ZR95	1.14E-06	1.23E-06	6.72E-10	0.00E+00	0.00E+00	0.00E+00
NB95M	9.24E-08	1.01E-07	5.14E-11	0.00E+00	0.00E+00	0.00E+00
NB95	1.18E-06	1.28E-06	6.94E-10	0.00E+00	0.00E+00	0.00E+00
ZR97	2.84E-07	3.09E-07	1.65E-10	0.00E+00	0.00E+00	0.00E+00
NB97M	1.12E-06	1.21E-06	6.62E-10	0.00E+00	0.00E+00	0.00E+00
NB97	1.00E-06	1.09E-06	5.96E-10	0.00E+00	0.00E+00	0.00E+00
NB94	2.43E-06	2.63E-06	1.43E-09	0.00E+00	0.00E+00	0.00E+00
MO99	2.30E-07	2.49E-07	1.33E-10	0.00E+00	0.00E+00	0.00E+00
TC99M	1.86E-07	2.07E-07	9.18E-11	0.00E+00	0.00E+00	0.00E+00
TC99	5.11E-11	4.95E-11	2.11E-14	0.00E+00	0.00E+00	0.00E+00
TC101	5.08E-07	5.53E-07	2.93E-10	0.00E+00	0.00E+00	0.00E+00
RU103	7.10E-07	7.71E-07	4.19E-10	0.00E+00	0.00E+00	0.00E+00
PD103	2.42E-09	2.84E-09	4.19E-13	0.00E+00	0.00E+00	0.00E+00
RH103M	2.78E-10	3.26E-10	4.10E-14	0.00E+00	0.00E+00	0.00E+00
RU105	1.20E-06	1.30E-06	7.06E-10	0.00E+00	0.00E+00	0.00E+00
RH105	1.17E-07	1.28E-07	6.81E-11	0.00E+00	0.00E+00	0.00E+00
RU106	3.28E-07	3.53E-07	1.94E-10	0.00E+00	0.00E+00	0.00E+00
PD107	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PD109	1.40E-08	1.57E-08	5.06E-12	0.00E+00	0.00E+00	0.00E+00
AG110M	4.34E-06	4.69E-06	2.53E-09	0.00E+00	0.00E+00	0.00E+00
AG111	4.07E-08	4.43E-08	2.36E-11	0.00E+00	0.00E+00	0.00E+00
CD109	9.27E-09	1.07E-08	2.49E-12	0.00E+00	0.00E+00	0.00E+00
CD113M	2.19E-10	2.11E-10	1.08E-13	0.00E+00	0.00E+00	0.00E+00
CD115M	3.69E-08	3.97E-08	2.15E-11	0.00E+00	0.00E+00	0.00E+00
CD115	3.53E-07	3.83E-07	2.09E-10	0.00E+00	0.00E+00	0.00E+00
IN115M	2.33E-07	2.55E-07	1.35E-10	0.00E+00	0.00E+00	0.00E+00
IN111	5.87E-07	6.45E-07	3.19E-10	0.00E+00	0.00E+00	0.00E+00
IN114M	1.36E-07	1.49E-07	7.71E-11	0.00E+00	0.00E+00	0.00E+00
SN113	1.20E-08	1.36E-08	4.79E-12	0.00E+00	0.00E+00	0.00E+00
IN113M	3.82E-07	4.16E-07	2.24E-10	0.00E+00	0.00E+00	0.00E+00
SN117M	2.15E-07	2.38E-07	1.08E-10	0.00E+00	0.00E+00	0.00E+00
SN119M	3.19E-09	3.77E-09	5.08E-13	0.00E+00	0.00E+00	0.00E+00
SN121M	1.90E-09	2.22E-09	3.31E-13	0.00E+00	0.00E+00	0.00E+00

Figure 3. List of GRDF.15 File (continued)

FGR12 air,water,soil(15 CM) DCFs (Sv/yr per Bq/n) (7 Aug 96 MAH)

nuclide	Air Submersion m3	Water Surface L	Soil 15 cm "m3"	Buried 0.15 m m3	Buried 0.5 m m3	Buried 1.0m m3
SN121	7.47E-11	7.25E-11	3.28E-14	0.00E+00	0.00E+00	0.00E+00
SN123	1.27E-08	1.35E-08	7.38E-12	0.00E+00	0.00E+00	0.00E+00
SN125	4.98E-07	5.41E-07	2.88E-10	0.00E+00	0.00E+00	0.00E+00
SB125	6.37E-07	6.92E-07	3.72E-10	0.00E+00	0.00E+00	0.00E+00
TE125M	1.43E-08	1.67E-08	2.55E-12	0.00E+00	0.00E+00	0.00E+00
SN126	6.65E-08	7.51E-08	2.49E-11	0.00E+00	0.00E+00	0.00E+00
SB126M	2.37E-06	2.57E-06	1.40E-09	0.00E+00	0.00E+00	0.00E+00
SB126	4.32E-06	4.71E-06	2.56E-09	0.00E+00	0.00E+00	0.00E+00
SB122	6.72E-07	7.32E-07	4.01E-10	0.00E+00	0.00E+00	0.00E+00
SB124	2.89E-06	3.12E-06	1.66E-09	0.00E+00	0.00E+00	0.00E+00
SB127	1.05E-06	1.14E-06	6.21E-10	0.00E+00	0.00E+00	0.00E+00
TE127M	4.64E-09	5.42E-09	9.11E-13	0.00E+00	0.00E+00	0.00E+00
TE127	7.63E-09	8.29E-09	4.45E-12	0.00E+00	0.00E+00	0.00E+00
SB129	2.25E-06	2.44E-06	1.31E-09	0.00E+00	0.00E+00	0.00E+00
TE129M	4.89E-08	5.35E-08	2.77E-11	0.00E+00	0.00E+00	0.00E+00
TE129	8.67E-08	9.45E-08	5.05E-11	0.00E+00	0.00E+00	0.00E+00
I 129	1.20E-08	1.40E-08	2.19E-12	0.00E+00	0.00E+00	0.00E+00
TE123M	2.05E-07	2.27E-07	1.04E-10	0.00E+00	0.00E+00	0.00E+00
TE131M	2.21E-06	2.40E-06	1.28E-09	0.00E+00	0.00E+00	0.00E+00
TE131	6.43E-07	7.00E-07	3.63E-10	0.00E+00	0.00E+00	0.00E+00
I 131	5.74E-07	6.28E-07	3.37E-10	0.00E+00	0.00E+00	0.00E+00
XE131M	1.23E-08	1.41E-08	3.75E-12	0.00E+00	0.00E+00	0.00E+00
TE132	3.25E-07	3.60E-07	1.75E-10	0.00E+00	0.00E+00	0.00E+00
I 132	3.53E-06	3.83E-06	2.07E-09	0.00E+00	0.00E+00	0.00E+00
TE133M	3.60E-06	3.91E-06	2.09E-09	0.00E+00	0.00E+00	0.00E+00
TE133	1.45E-06	1.58E-06	8.39E-10	0.00E+00	0.00E+00	0.00E+00
I 133	9.27E-07	1.01E-06	5.49E-10	0.00E+00	0.00E+00	0.00E+00
XE133M	4.32E-08	4.79E-08	2.11E-11	0.00E+00	0.00E+00	0.00E+00
XE133	4.92E-08	5.58E-08	1.69E-11	0.00E+00	0.00E+00	0.00E+00
TE134	1.34E-06	1.46E-06	7.76E-10	0.00E+00	0.00E+00	0.00E+00
I 134	4.10E-06	4.45E-06	2.38E-09	0.00E+00	0.00E+00	0.00E+00
XE122	1.52E-06	1.65E-06	8.95E-10	0.00E+00	0.00E+00	0.00E+00
XE125	3.75E-07	4.13E-07	2.04E-10	0.00E+00	0.00E+00	0.00E+00
I 125	1.65E-08	1.94E-08	2.79E-12	0.00E+00	0.00E+00	0.00E+00
CS134M	2.85E-08	3.20E-08	1.21E-11	0.00E+00	0.00E+00	0.00E+00
CS134	2.39E-06	2.59E-06	1.41E-09	0.00E+00	0.00E+00	0.00E+00
I 130	3.28E-06	3.55E-06	1.94E-09	0.00E+00	0.00E+00	0.00E+00
I 135	2.52E-06	2.73E-06	1.44E-09	0.00E+00	0.00E+00	0.00E+00
XE135M	6.43E-07	7.02E-07	3.82E-10	0.00E+00	0.00E+00	0.00E+00
XE135	3.75E-07	4.12E-07	2.13E-10	0.00E+00	0.00E+00	0.00E+00
CS135	1.78E-11	1.73E-11	6.46E-15	0.00E+00	0.00E+00	0.00E+00
XE137	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CS137	9.08E-07	9.87E-07	5.39E-10	0.00E+00	0.00E+00	0.00E+00
XE138	1.82E-06	1.97E-06	1.02E-09	0.00E+00	0.00E+00	0.00E+00
CS138	3.82E-06	4.13E-06	2.16E-09	0.00E+00	0.00E+00	0.00E+00
CS139	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BA139	6.84E-08	7.46E-08	3.63E-11	0.00E+00	0.00E+00	0.00E+00
BA140	2.71E-07	2.95E-07	1.58E-10	0.00E+00	0.00E+00	0.00E+00
LA140	3.69E-06	4.01E-06	2.11E-09	0.00E+00	0.00E+00	0.00E+00
CS136	3.34E-06	3.64E-06	1.95E-09	0.00E+00	0.00E+00	0.00E+00

Figure 3. List of GRDF.15 File (continued)

FGR12 air,water,soil(15 CM) DCFs (Sv/yr per Bq/n) (7 Aug 96 MAH)

nuclide	Air Submersion m3	Water Surface L	Soil 15 cm "m3"	Buried 0.15 m m3	Buried 0.5 m m3	Buried 1.0m m3
BA141	1.31E-06	1.43E-06	7.54E-10	0.00E+00	0.00E+00	0.00E+00
LA141	7.54E-08	8.07E-08	4.32E-11	0.00E+00	0.00E+00	0.00E+00
CE141	1.08E-07	1.20E-07	5.30E-11	0.00E+00	0.00E+00	0.00E+00
BA142	1.62E-06	1.77E-06	9.33E-10	0.00E+00	0.00E+00	0.00E+00
LA142	4.54E-06	4.92E-06	2.50E-09	0.00E+00	0.00E+00	0.00E+00
CE143	4.07E-07	4.46E-07	2.29E-10	0.00E+00	0.00E+00	0.00E+00
PR143	6.62E-10	6.37E-10	3.63E-13	0.00E+00	0.00E+00	0.00E+00
CE144	2.69E-08	3.01E-08	1.20E-11	0.00E+00	0.00E+00	0.00E+00
PR144M	8.80E-09	1.02E-08	2.31E-12	0.00E+00	0.00E+00	0.00E+00
PR144	6.15E-08	6.54E-08	3.56E-11	0.00E+00	0.00E+00	0.00E+00
PR142	9.93E-08	1.07E-07	5.64E-11	0.00E+00	0.00E+00	0.00E+00
ND147	1.95E-07	2.14E-07	1.04E-10	0.00E+00	0.00E+00	0.00E+00
PM147	2.19E-11	2.21E-11	8.42E-15	0.00E+00	0.00E+00	0.00E+00
SM147	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PM148M	3.05E-06	3.31E-06	1.80E-09	0.00E+00	0.00E+00	0.00E+00
PM148	9.11E-07	9.87E-07	5.27E-10	0.00E+00	0.00E+00	0.00E+00
PM149	1.71E-08	1.84E-08	9.81E-12	0.00E+00	0.00E+00	0.00E+00
PM151	4.76E-07	5.20E-07	2.69E-10	0.00E+00	0.00E+00	0.00E+00
SM151	1.14E-12	1.34E-12	1.66E-16	0.00E+00	0.00E+00	0.00E+00
SM153	7.19E-08	8.12E-08	2.66E-11	0.00E+00	0.00E+00	0.00E+00
EU152M	4.48E-07	4.87E-07	2.58E-10	0.00E+00	0.00E+00	0.00E+00
EU152	1.78E-06	1.94E-06	1.02E-09	0.00E+00	0.00E+00	0.00E+00
EU154	1.94E-06	2.10E-06	1.11E-09	0.00E+00	0.00E+00	0.00E+00
EU155	7.85E-08	8.85E-08	3.07E-11	0.00E+00	0.00E+00	0.00E+00
EU156	2.13E-06	2.30E-06	1.20E-09	0.00E+00	0.00E+00	0.00E+00
GD153	1.17E-07	1.33E-07	4.13E-11	0.00E+00	0.00E+00	0.00E+00
GD159	6.97E-08	7.66E-08	3.75E-11	0.00E+00	0.00E+00	0.00E+00
TB160	1.75E-06	1.89E-06	1.01E-09	0.00E+00	0.00E+00	0.00E+00
TB161	3.22E-08	3.67E-08	9.21E-12	0.00E+00	0.00E+00	0.00E+00
DY165	3.78E-08	4.15E-08	1.99E-11	0.00E+00	0.00E+00	0.00E+00
HO166M	2.66E-06	2.90E-06	1.55E-09	0.00E+00	0.00E+00	0.00E+00
HO166	4.48E-08	4.87E-08	2.26E-11	0.00E+00	0.00E+00	0.00E+00
ER169	5.49E-11	5.33E-11	2.34E-14	0.00E+00	0.00E+00	0.00E+00
ER171	5.61E-07	6.18E-07	3.11E-10	0.00E+00	0.00E+00	0.00E+00
TA182	2.02E-06	2.19E-06	1.14E-09	0.00E+00	0.00E+00	0.00E+00
W 181	4.42E-08	5.08E-08	1.29E-11	0.00E+00	0.00E+00	0.00E+00
W 185	1.69E-10	1.75E-10	7.25E-14	0.00E+00	0.00E+00	0.00E+00
W 187	7.19E-07	7.84E-07	4.16E-10	0.00E+00	0.00E+00	0.00E+00
RE187	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
OS185	1.08E-06	1.18E-06	6.24E-10	0.00E+00	0.00E+00	0.00E+00
OS191	1.01E-07	1.14E-07	4.04E-11	0.00E+00	0.00E+00	0.00E+00
IR192	1.23E-06	1.35E-06	7.19E-10	0.00E+00	0.00E+00	0.00E+00
HG203	3.56E-07	3.91E-07	2.02E-10	0.00E+00	0.00E+00	0.00E+00
TH230	5.49E-10	6.21E-10	2.02E-13	0.00E+00	0.00E+00	0.00E+00
RA226	9.93E-09	1.10E-08	5.20E-12	0.00E+00	0.00E+00	0.00E+00
RN222	2.79E-06	3.03E-06	1.59E-09	0.00E+00	0.00E+00	0.00E+00
PB210	1.78E-09	2.07E-09	4.13E-13	0.00E+00	0.00E+00	0.00E+00
BI210	1.04E-09	9.98E-10	5.87E-13	0.00E+00	0.00E+00	0.00E+00
PO210	1.31E-11	1.42E-11	7.73E-15	0.00E+00	0.00E+00	0.00E+00
U 232	4.48E-10	5.08E-10	1.50E-13	0.00E+00	0.00E+00	0.00E+00

Figure 3. List of GRDF.15 File (continued)

FGR12 air,water,soil(15 CM) DCFs (Sv/yr per Bq/n) (7 Aug 96 MAH)

nuclide	Air Submersion m3	Water Surface L	Soil 15 cm "m3"	Buried 0.15 m m3	Buried 0.5 m m3	Buried 1.0m m3
TH232	2.75E-10	3.14E-10	8.77E-14	0.00E+00	0.00E+00	0.00E+00
RA228	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
AC228	1.51E-06	1.64E-06	8.70E-10	0.00E+00	0.00E+00	0.00E+00
TH228	2.90E-09	3.23E-09	1.32E-12	0.00E+00	0.00E+00	0.00E+00
RA224	1.55E-08	1.69E-08	8.62E-12	0.00E+00	0.00E+00	0.00E+00
PB212	2.17E-07	2.40E-07	1.14E-10	0.00E+00	0.00E+00	0.00E+00
BI212	2.30E-06	2.49E-06	1.27E-09	0.00E+00	0.00E+00	0.00E+00
U 234	2.41E-10	2.76E-10	6.75E-14	0.00E+00	0.00E+00	0.00E+00
U 236	1.58E-10	1.83E-10	3.60E-14	0.00E+00	0.00E+00	0.00E+00
U 235	2.27E-07	2.51E-07	1.18E-10	0.00E+00	0.00E+00	0.00E+00
TH231	1.65E-08	1.86E-08	6.12E-12	0.00E+00	0.00E+00	0.00E+00
PA231	5.42E-08	5.96E-08	3.03E-11	0.00E+00	0.00E+00	0.00E+00
AC227	1.84E-10	2.05E-10	8.26E-14	0.00E+00	0.00E+00	0.00E+00
TH227	1.54E-07	1.69E-07	8.36E-11	0.00E+00	0.00E+00	0.00E+00
FR223	7.22E-08	8.06E-08	3.19E-11	0.00E+00	0.00E+00	0.00E+00
RA223	4.25E-07	4.67E-07	2.33E-10	0.00E+00	0.00E+00	0.00E+00
U 237	1.88E-07	2.10E-07	8.77E-11	0.00E+00	0.00E+00	0.00E+00
NP237	3.25E-08	3.66E-08	1.31E-11	0.00E+00	0.00E+00	0.00E+00
PA233	2.95E-07	3.23E-07	1.63E-10	0.00E+00	0.00E+00	0.00E+00
U 233	5.14E-10	5.74E-10	2.28E-13	0.00E+00	0.00E+00	0.00E+00
TH229	1.21E-07	1.35E-07	5.36E-11	0.00E+00	0.00E+00	0.00E+00
RA225	8.80E-09	1.02E-08	1.86E-12	0.00E+00	0.00E+00	0.00E+00
AC225	2.71E-07	2.96E-07	1.54E-10	0.00E+00	0.00E+00	0.00E+00
U 238	1.08E-10	1.25E-10	1.74E-14	0.00E+00	0.00E+00	0.00E+00
TH234	3.33E-08	3.60E-08	1.73E-11	0.00E+00	0.00E+00	0.00E+00
PA234	2.95E-06	3.20E-06	1.70E-09	0.00E+00	0.00E+00	0.00E+00
PU236	2.00E-10	2.33E-10	3.78E-14	0.00E+00	0.00E+00	0.00E+00
PU237	6.37E-08	7.14E-08	2.73E-11	0.00E+00	0.00E+00	0.00E+00
AM242M	1.00E-09	1.15E-09	2.84E-13	0.00E+00	0.00E+00	0.00E+00
AM242	1.94E-08	2.18E-08	8.42E-12	0.00E+00	0.00E+00	0.00E+00
CM242	1.79E-10	2.10E-10	2.86E-14	0.00E+00	0.00E+00	0.00E+00
PU242	1.26E-10	1.47E-10	2.16E-14	0.00E+00	0.00E+00	0.00E+00
NP238	8.58E-07	9.29E-07	4.98E-10	0.00E+00	0.00E+00	0.00E+00
PU238	1.54E-10	1.80E-10	2.54E-14	0.00E+00	0.00E+00	0.00E+00
CM244	1.55E-10	1.81E-10	2.13E-14	0.00E+00	0.00E+00	0.00E+00
PU244	9.37E-11	1.10E-10	1.27E-14	0.00E+00	0.00E+00	0.00E+00
U 240	5.12E-07	5.55E-07	3.00E-10	0.00E+00	0.00E+00	0.00E+00
PU240	1.50E-10	1.75E-10	2.47E-14	0.00E+00	0.00E+00	0.00E+00
CM245	1.25E-07	1.39E-07	5.68E-11	0.00E+00	0.00E+00	0.00E+00
PU241	2.29E-12	2.55E-12	9.93E-16	0.00E+00	0.00E+00	0.00E+00
AM241	2.58E-08	2.96E-08	7.38E-12	0.00E+00	0.00E+00	0.00E+00
CM246	1.41E-10	1.66E-10	1.96E-14	0.00E+00	0.00E+00	0.00E+00
CM247	4.73E-07	5.16E-07	2.78E-10	0.00E+00	0.00E+00	0.00E+00
CM243	1.85E-07	2.05E-07	9.52E-11	0.00E+00	0.00E+00	0.00E+00
PU243	3.25E-08	3.64E-08	1.32E-11	0.00E+00	0.00E+00	0.00E+00
AM243	6.87E-08	7.79E-08	2.40E-11	0.00E+00	0.00E+00	0.00E+00
NP239	2.43E-07	2.68E-07	1.23E-10	0.00E+00	0.00E+00	0.00E+00
PU239	1.34E-10	1.51E-10	4.79E-14	0.00E+00	0.00E+00	0.00E+00
CM248	1.07E-10	1.26E-10	1.48E-14	0.00E+00	0.00E+00	0.00E+00
CF252	1.60E-10	1.86E-10	2.96E-14	0.00E+00	0.00E+00	0.00E+00

For each set of input data, the files with extension ".flg", ".inp" “, ".pti", and ".vec" are used by the GENII-S code to store the input data, and they must be used together for computer runs. The input files with extensions ".flg", ".inp", ".pti", and ".vec" are used by the computer code to perform the calculations and are not easy to read.

The output file has extension " .out". A total of three data sets are generated as a result of this analysis, and summary results are provided in Section 3 of this attachment.

3. RESULTS

As a result of the changes from Revision 00 to Revision 01 of this calculation, the source terms for four nuclides were slightly changed. Three of the nuclide source terms, H-3, Kr-85 and I-129, were reduced due to the re-classification of three pool events (Events 1-06, 1-09, and 1-11) from Revision 00 as Category 2 events. The fourth nuclide, Co-60, increased slightly with the single SFA drop onto the hot cell floor (Attachment VII, Event 1-13) due to an error in the crud source term calculation in Revision 00. These were the only changes to the GENII-S dose calculations for Category 1 releases documented in Revision 00 of this calculation. As a result of the source term input changes, the GENII-S runs PRCHGS and PRCHP1 were slightly modified. The original (see Table 1) and modified source terms are shown in Table 5 below:

Table 5. Source Term Changes from Revision 01

GENII-S Run	Nuclide	Original Source Term (rem/yr)	Modified Source Term (rem/yr)	Ratio of Modified to Original
PRCHGS	H-3	1.46E+02	1.34E+02	0.918
	Kr-85	1.45E+03	1.33E+03	0.917
	I-129	2.82E-02	2.58E-02	0.915
PRCHP1	Co-60	1.97E-02	2.23E-02	1.132

In order to assess the impact on the results from Revision 00, the ratio of the modified source term to the original source term was applied to the applicable dose results for each of the modified nuclides. The results of this assessment are summarized in Table 6.

Table 6. Summary of Preclosure Offsite Dose Calculations

GENII-S Run	Inhalation Effective Dose Equivalent (rem/yr)	Ingestion Effective Dose Equivalent (rem/yr)	External Dose (rem/yr)	Internal Effective Dose Equivalent (rem/yr)	Total Effective Dose Equivalent (rem/yr)	Dose Percentage (%)
PRCHSF	0.0E+00	0.0E+00	2.5E-07	0.0E+00	2.5E-07	0.4%
PRCHSB	4.5E-10	2.1E-10	2.9E-06	6.6E-10	2.9E-06	4.7%
PRCHGS*	6.1E-07	0.0E+00	7.9E-08	6.1E-07	6.9E-07	1.1%
PRCHP1*	6.4E-06	7.1E-07	9.8E-08	7.2E-06	7.3E-06	11.8%
PRCHP2	3.7E-05	1.0E-05	1.5E-07	4.7E-05	4.7E-05	75.7%
PRCHP3	3.7E-06	2.2E-07	2.1E-10	4.0E-06	4.0E-06	6.4%
Total	**4.8E-05**	**1.1E-05**	**3.5E-06**	**5.9E-05**	**6.2E-05**	**100%**

* The dose values for GENII-S runs PRCHGS and PRCHP1 changed slightly from Revision 00 to Revision 01 of this calculation due to the re-classification of three Category 1 events as Category 2 events and a minor change in the quantity of Co-60 released in Event 1-13.

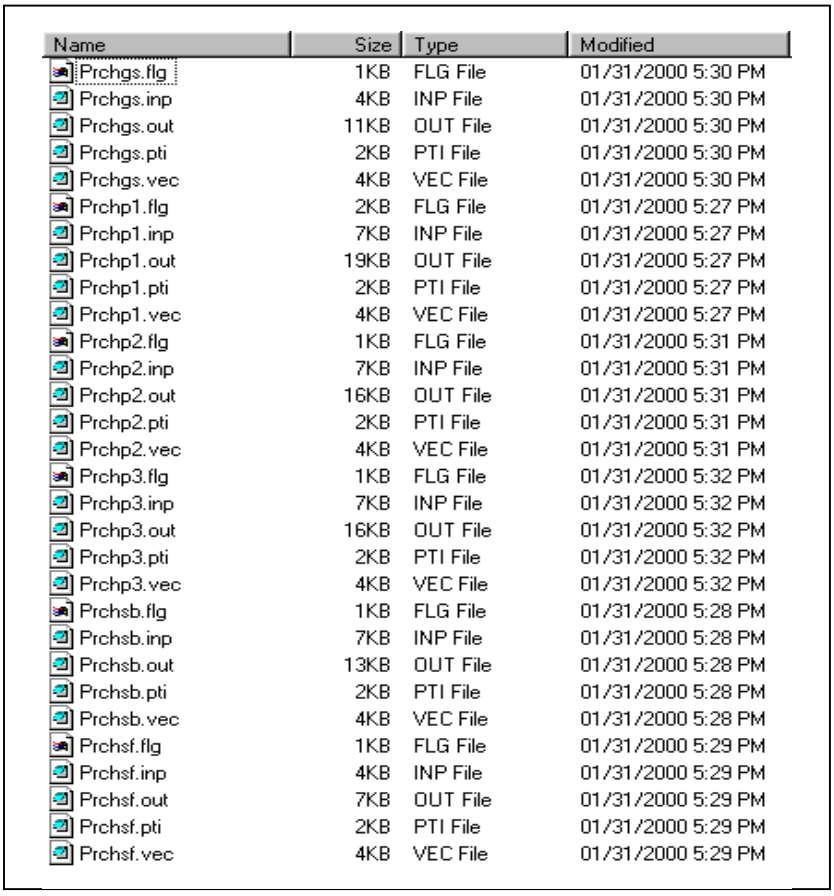
The net effect of the source term changes on the dose results is negligible. The decreased gaseous source terms in PRCHGS offset the increased Co-60 source term in PRCHP1. As shown in Table 6, the TEDE to an individual member of the public due to all Category 1 releases from the MGR is identical to that presented in Revision 00 of this calculation, 6.2E-05 rem/yr.

GENII-S input parameters for mass loading (DTN: MO9910RIB00061.000) and leaching coefficients (DTN: SN9912T0512299.001) have been superseded by DTNs MO0003RIB00061.001 and SN0002T0512299.003, respectively, since Revision 00 of this calculation was approved. However, there were no changes to the mass loading parameter and the leaching coefficients for the dominant dose-contributing nuclides increased, thereby reducing the effective inhalation, submersion and ingestion doses to the receptor. Thus, the dose results from Revision 00 are conservative and still valid.

The committed dose equivalent (CDE) for the lens of the eye and skin were not calculated in the GENII-S dose assessment due to limitations with the GENII-S code.

The GENII-S input and output files used to calculate offsite doses due to Category 1 events (including normal operational releases) are listed in Figure 4.

Figure 4. GENII-S Input and Output Files



Name	Size	Type	Modified
Prchgs.flg	1KB	FLG File	01/31/2000 5:30 PM
Prchgs.inp	4KB	INP File	01/31/2000 5:30 PM
Prchgs.out	11KB	OUT File	01/31/2000 5:30 PM
Prchgs.pti	2KB	PTI File	01/31/2000 5:30 PM
Prchgs.vec	4KB	VEC File	01/31/2000 5:30 PM
Prchp1.flg	2KB	FLG File	01/31/2000 5:27 PM
Prchp1.inp	7KB	INP File	01/31/2000 5:27 PM
Prchp1.out	19KB	OUT File	01/31/2000 5:27 PM
Prchp1.pti	2KB	PTI File	01/31/2000 5:27 PM
Prchp1.vec	4KB	VEC File	01/31/2000 5:27 PM
Prchp2.flg	1KB	FLG File	01/31/2000 5:31 PM
Prchp2.inp	7KB	INP File	01/31/2000 5:31 PM
Prchp2.out	16KB	OUT File	01/31/2000 5:31 PM
Prchp2.pti	2KB	PTI File	01/31/2000 5:31 PM
Prchp2.vec	4KB	VEC File	01/31/2000 5:31 PM
Prchp3.flg	1KB	FLG File	01/31/2000 5:32 PM
Prchp3.inp	7KB	INP File	01/31/2000 5:32 PM
Prchp3.out	16KB	OUT File	01/31/2000 5:32 PM
Prchp3.pti	2KB	PTI File	01/31/2000 5:32 PM
Prchp3.vec	4KB	VEC File	01/31/2000 5:32 PM
Prchsb.flg	1KB	FLG File	01/31/2000 5:28 PM
Prchsb.inp	7KB	INP File	01/31/2000 5:28 PM
Prchsb.out	13KB	OUT File	01/31/2000 5:28 PM
Prchsb.pti	2KB	PTI File	01/31/2000 5:28 PM
Prchsb.vec	4KB	VEC File	01/31/2000 5:28 PM
Prchsf.flg	1KB	FLG File	01/31/2000 5:29 PM
Prchsf.inp	4KB	INP File	01/31/2000 5:29 PM
Prchsf.out	7KB	OUT File	01/31/2000 5:29 PM
Prchsf.pti	2KB	PTI File	01/31/2000 5:29 PM
Prchsf.vec	4KB	VEC File	01/31/2000 5:29 PM

Attachment V

Non-Involved Worker Dose Calculations

The following data in this attachment is from file **Cat. 1 Worker Dose.xls** (Attachment I):

Worksheet	Description	Page
Events-Frequencies	List of Category 1 Events and Frequencies	V-2
Normal Releases	Dose Calculations for Surface and Subsurface Normal Releases	V-3
Avg Dose	Inhalation Dose (rem/FA) for Average Fuels (PWR & BWR)	V-4 to V-5
Max Dose	Inhalation Dose (rem/FA) for Maximum Fuels (PWR & BWR)	V-6 to V-7
Crud	Crud Source Term Calculations	V-8
Groupings	Nuclides and Inhalation Dose Sorted by Group	V-9
Grouped Sources	Total Inhalation Dose for Each Group (sum of nuclides in each group)	V-10
RFs	Release Fractions for CSNF	V-11
χ-Q Values	Maximum Sector Acute χ/Q Values at 100-m, 5-km, 8-km and 11-km	V-12
The worksheets from Submersion (V-13) through Whole Body (V-21) are shown for Event 1-11, for illustration purposes only. The results of these worksheets for each Category 1 event are captured in the individual Summary worksheets (V-37 through V-50).		
Submersion	Submersion Dose Due to H-3 and Kr-85	V-13
Gonad	Inhalation Dose to the Gonad	V-14
Breast	Inhalation Dose to the Breast	V-15
Lung	Inhalation Dose to the Lung	V-16
Marrow	Inhalation Dose to the Red Marrow	V-17
Bone Surface	Inhalation Dose to the Bone Surface	V-18
Thyroid	Inhalation Dose to the Thyroid	V-19
Remainder	Inhalation Dose to the Remainder of Organs	V-20
Whole Body	Effective Inhalation Dose to the Whole Body	V-21
Annual Dose	Annual TEDE, Max. Organ, Eye and Skin Doses for All Category 1 DBEs and Normal Releases	V-22
Input	Input Parameters for each Category 1 event	V-23 to V-36
Summary	Output Summary for each Category 1 event	V-37 to V-50
Test Cases	Validation Test Cases for Formulas contained in this workbook	V51 to V52

Category 1 Event Frequencies

Event #	Category 1 Events	Location	Occurs in Pool?	Material at Risk (# SFAs)		Sequence Frequency
				PWR	BWR	
1-01	SFA Drop Onto Another SFA in Cask	Cask Unloading	Y	2	2	2.34E-01
1-02	SFA Collision	Cask Unloading Pool	Y	1	1	3.90E-02
1-03	SFA Drop Onto Empty Basket	Cask Unloading	Y	1	1	4.22E-02
1-04	SFA Drop Onto Another SFA in Basket Staging Rack (Lowering Into)	Cask Unloading Pool	Y	2	2	1.92E-01
1-05	Basket Drop Onto Another Basket in Basket Staging Rack (Lifting Out)	Cask Unloading Pool	Y	8	16	4.10E-02
1-06	Basket Drop Onto Another Basket in Pool (Transfer Into Pool Storage)	ATS Pool	Y	8	16	4.10E-02
1-07	Basket Drop Onto Another Basket in Pool (Transfer Out of Pool Storage)	ATS Pool	Y	8	16	4.10E-02
1-08	Basket Drop Onto Transfer Cart or Pool Floor	ATS Pool	Y	4	8	4.10E-02
1-09	Basket Drop Back Into Pool	ATS Pool	Y	4	8	4.10E-02
1-10	Basket Drop Onto ATS Hot Cell Floor	ATS Hot Cell	N	4	8	4.10E-02
1-11	Basket Drop Onto Another Basket in Dryer	ATS Hot Cell	N	8	16	4.10E-02
1-12	SFA Drop Onto Another SFA in Dryer	ATS Hot Cell	N	2	2	2.34E-01
1-13	SFA Drop Onto ATS Hot Cell Floor	ATS Hot Cell	N	1	1	2.34E-01
1-14	SFA Drop Onto Another SFA in DC	ATS Hot Cell	N	2	2	2.34E-01

Normal (Chronic) Releases from Surface & Subsurface Facilities

Normal Ops Release - Surface (Ci/yr)		Source
Kr-85	4.01E+03	(CRWMS M&O 2000a)

Normal Ops Release - Subsurface (Ci/yr)		Source
N-16	2.909E-03	(CRWMS M&O 2000b)
Ar-41	5.728E+01	
Na-24	6.471E-03	
Al-28	3.963E-03	
Si-31	7.170E-04	
K-42	8.041E-04	
Fe-55	1.492E-04	

Dose Coefficients for Air Submersion from Federal Guidance Report #12 (Eckerman and Ryman 1993, Table III.1)

	Dose Coefficient (Sv-m^3/Bq-s)		
Nuclide	Effective	Skin	Eye
Kr-85	1.19E-16	1.32E-14	0.00E+00
N-16	0.00E+00	0.00E+00	0.00E+00
Ar-41	6.50E-14	1.01E-13	0.00E+00
Na-24	2.18E-13	2.75E-13	0.00E+00
Al-28	9.28E-14	1.88E-13	0.00E+00
Si-31	1.17E-16	3.78E-14	0.00E+00
K-42	1.46E-14	1.15E-13	0.00E+00
Fe-55	0.00E+00	0.00E+00	0.00E+00

Submersion Dose (DDE) Calculation for Normal Releases:

Nuclide	Annual Release (Ci/yr)	Dose Coefficient-Effective (Sv-m^3/Bq-s)	Conversion Factor (rem-Bq/Ci-Sv)	100-m Chronic X/Q (s/m^3)	Submersion DDE (rem/yr)	Skin Dose (rem/yr)
Surface Release						
Kr-85	4.01E+03	1.19E-16	3.70E+12	4.77E-04	8.42E-04	9.34E-02
Subsurface Release						
N-16	2.91E-03	0	3.70E+12	4.77E-04	0.00E+00	0.00E+00
Ar-41	5.73E+01	6.50E-14	3.70E+12	4.77E-04	6.57E-03	1.02E-02
Na-24	6.47E-03	2.18E-13	3.70E+12	4.77E-04	2.49E-06	3.14E-06
Al-28	3.96E-03	9.28E-14	3.70E+12	4.77E-04	6.49E-07	1.31E-06
Si-31	7.17E-04	1.17E-16	3.70E+12	4.77E-04	1.48E-10	4.78E-08
K-42	8.04E-04	1.46E-14	3.70E+12	4.77E-04	2.07E-08	1.63E-07
Fe-55	1.49E-04	0	3.70E+12	4.77E-04	0.00E+00	0.00E+00
				Totals:	6.57E-03	1.02E-02

Inhalation Dose for Average PWR Fuel

Nuclide	AVERAGE PWR INHALATION DOSE (REM/FA)*								MAR (Curies/FA)
	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Whole Body	
Ac-227	2.12E+03	6.31E-01	9.17E+04	1.39E+04	1.73E+05	3.85E-01	7.98E+03	2.08E+04	1.61E-05
Am-241	2.38E+11	1.96E+07	1.35E+11	1.27E+12	1.59E+13	1.17E+07	5.73E+11	8.77E+11	1.98E+03
Am-242m	7.59E+08	3.26E+04	9.93E+07	4.00E+09	5.01E+10	1.33E+04	1.77E+09	2.72E+09	6.39E+00
Am-243	2.65E+09	1.24E+06	1.45E+09	1.41E+10	1.77E+11	6.75E+05	6.30E+09	9.72E+09	2.20E+01
C-14	7.81E+00	7.81E+00	7.81E+00	7.81E+00	7.81E+00	7.81E+00	7.81E+00	7.81E+00	3.32E-01
Cd-113m	1.34E+05	1.34E+05	1.16E+07	1.34E+05	1.34E+05	1.34E+05	5.27E+06	3.05E+06	7.66E+00
Cl-36	1.27E+01	1.27E+01	1.15E+03	1.27E+01	1.27E+01	1.27E+01	1.35E+01	1.49E+02	6.80E-03
Cm-242	1.11E+07	1.84E+04	3.02E+08	7.60E+07	9.50E+08	1.83E+04	4.78E+07	9.10E+07	5.27E+00
Cm-243	7.89E+08	2.40E+05	7.39E+08	4.50E+09	5.60E+10	1.46E+05	2.20E+09	3.16E+09	1.03E+01
Cm-244	8.00E+10	5.23E+06	9.71E+10	4.72E+11	5.89E+12	5.08E+06	2.41E+11	3.37E+11	1.36E+03
Cm-245	3.83E+07	7.60E+03	2.04E+07	2.03E+08	2.54E+09	4.18E+03	9.04E+07	1.40E+08	3.07E-01
Cm-246	1.29E+07	1.54E+03	7.00E+06	6.85E+07	8.54E+08	8.70E+02	3.06E+07	4.71E+07	1.04E-01
Co-60	5.51E+06	2.13E+07	4.00E+08	1.99E+07	1.56E+07	1.88E+07	4.17E+07	6.84E+07	3.13E+02
Cs-134	1.21E+06	1.01E+06	1.10E+06	1.10E+06	1.03E+06	1.03E+06	1.30E+06	1.17E+06	2.52E+01
Cs-135	1.55E+03	1.55E+03	1.83E+03	1.55E+03	1.55E+03	1.55E+03	1.55E+03	1.59E+03	3.50E-01
Cs-137	1.33E+09	1.19E+09	1.34E+09	1.26E+09	1.21E+09	1.21E+09	1.39E+09	1.31E+09	4.11E+04
Eu-154	2.90E+07	3.85E+07	1.97E+08	2.63E+08	1.30E+09	1.77E+07	2.81E+08	1.92E+08	6.71E+02
Eu-155	6.80E+04	1.17E+05	2.27E+06	2.73E+06	2.90E+07	4.58E+04	2.12E+06	2.14E+06	5.16E+01
Fe-55	2.30E+03	2.23E+03	1.36E+04	2.26E+03	2.25E+03	2.38E+03	5.61E+03	4.64E+03	3.47E+00
H-3	7.30E+03	7.30E+03	7.30E+03	7.30E+03	7.30E+03	7.30E+03	7.30E+03	7.30E+03	1.14E+02
I-129	7.07E+00	1.70E+01	2.56E+01	1.14E+01	1.12E+01	1.27E+05	9.61E+00	3.82E+03	2.20E-02
Kr-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.13E+03
Nb-93m	7.46E+03	2.10E+03	3.10E+06	5.48E+03	1.37E+04	5.48E+02	1.46E+04	3.80E+05	1.30E+01
Nb-94	1.37E+04	6.95E+04	2.32E+06	7.02E+04	6.12E+04	6.89E+04	1.38E+05	3.46E+05	8.39E-01
Ni-59	8.43E+02	8.12E+02	9.28E+03	8.20E+02	8.12E+02	8.82E+02	1.08E+03	1.92E+03	2.09E+00
Ni-63	2.30E+05	2.30E+05	2.86E+06	2.30E+05	2.30E+05	2.30E+05	3.42E+05	5.80E+05	2.52E+02
Np-237	2.71E+07	1.54E+04	1.47E+07	2.39E+08	2.99E+09	1.22E+04	2.14E+07	1.33E+08	2.47E-01
Pa-231	3.36E-01	6.21E-01	8.21E+04	3.16E+04	3.96E+05	4.89E-01	2.33E+01	2.55E+04	2.97E-05
Pb-210	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pd-107	3.27E-02	3.27E-02	8.87E+03	1.77E-01	4.70E-01	3.27E-02	3.02E+01	1.07E+03	8.41E-02
Pm-147	3.63E+00	1.59E+01	3.41E+07	7.09E+05	8.85E+06	8.72E+00	6.87E+05	4.65E+06	1.19E+02
Pu-238	8.81E+10	3.73E+06	2.71E+12	4.91E+11	6.14E+12	3.27E+06	2.32E+11	6.60E+11	2.29E+03
Pu-239	7.86E+09	2.61E+05	2.12E+11	4.30E+10	5.38E+11	2.46E+05	1.98E+10	5.46E+10	1.77E+02
Pu-240	1.41E+10	5.09E+05	3.80E+11	7.73E+10	9.66E+11	4.42E+05	3.55E+10	9.81E+10	3.18E+02
Pu-241	2.52E+10	1.96E+06	2.91E+11	1.31E+11	1.63E+12	8.36E+05	5.50E+10	1.22E+11	2.47E+04
Pu-242	6.92E+07	2.64E+03	1.86E+09	3.79E+08	4.74E+09	2.25E+03	1.74E+08	4.81E+08	1.64E+00
Ra-226	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ra-228	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-106	5.92E+01	8.10E+01	4.73E+04	8.01E+01	7.33E+01	7.83E+01	5.46E+02	5.88E+03	1.23E-02
Sb-125	1.29E+04	1.49E+04	7.80E+05	1.92E+04	3.51E+04	1.16E+04	5.21E+04	1.19E+05	9.71E+00
Se-79	1.01E+02	1.01E+02	1.66E+03	1.01E+02	1.01E+02	1.01E+02	6.37E+02	4.49E+02	4.57E-02
Sm-147	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sm-151	3.15E+01	1.16E+02	2.55E+06	8.59E+06	1.08E+08	1.03E+01	5.86E+06	6.33E+06	2.11E+02
Sn-126	7.05E+03	7.68E+03	2.15E+05	2.41E+04	4.74E+04	6.98E+03	1.71E+04	3.84E+04	3.85E-01
Sr-90	2.66E+08	2.66E+08	3.75E+08	3.38E+10	7.32E+10	2.66E+08	3.38E+08	6.51E+09	2.72E+04
Tc-99	1.33E+03	1.33E+03	5.55E+05	1.33E+03	1.33E+03	3.56E+04	2.08E+04	7.47E+04	8.99E+00
Th-229	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Th-230	9.42E+01	9.42E+01	1.64E+05	3.83E+04	4.77E+05	9.42E+01	2.45E+02	3.87E+04	1.48E-04
Th-232	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-232	1.28E+03	2.02E+03	1.12E+08	3.55E+04	5.42E+05	1.84E+03	4.44E+04	1.35E+07	2.05E-02
U-233	4.05E-01	4.11E-01	4.58E+04	1.11E+01	1.75E+02	4.07E-01	1.63E+01	5.51E+03	4.07E-05
U-234	6.64E+03	6.71E+03	7.46E+08	1.81E+05	2.83E+06	6.64E+03	2.66E+05	8.98E+07	6.77E-01
U-235	7.73E+01	1.46E+02	7.52E+06	1.95E+03	2.86E+04	1.12E+02	2.78E+03	9.04E+05	7.36E-03
U-236	1.60E+03	1.62E+03	1.79E+08	4.35E+04	6.81E+05	1.60E+03	7.57E+02	2.16E+07	1.72E-01
U-238	1.33E+03	1.59E+03	1.46E+08	3.77E+04	5.53E+05	1.49E+03	5.26E+04	1.75E+07	1.48E-01
Zr-93	1.85E+01	3.97E+01	1.09E+04	1.49E+05	1.83E+06	1.47E+01	5.09E+02	7.43E+04	8.94E-01

Nuclide	AVERAGE PWR SUBMERSION DOSE RATE (rem-m^3/FA-s)**										MAR (Curies/FA)
	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Whole Body	Skin	Eye Lens	
H-3	0.00E+00	0.00E+00	1.16E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.40E-04	0.00E+00	0	1.14E+02
Kr-85	4.89E-01	5.60E-01	4.77E-01	4.56E-01	9.20E-01	4.93E-01	4.56E-01	4.98E-01	5.52E+01	0	1.13E+03
Totals:	4.89E-01	5.60E-01	4.78E-01	4.56E-01	9.20E-01	4.93E-01	4.56E-01	4.98E-01	5.52E+01	0.00E+00	

* Inhalation organ doses are cut/pasted from SR Source Terms.xls/Avg PWR/BWR Dose

** Submersion organ doses are cut/pasted from SR Source Terms.xls/Submersion Dose

Inhalation Dose for Average BWR Fuel

Nuclide	AVERAGE BWR INHALATION DOSE (REM/FA)*								MAR (Curies/FA)
	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Whole Body	
Ac-227	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Am-241	6.71E+10	5.51E+06	3.80E+10	3.59E+11	4.48E+12	3.30E+06	1.61E+11	2.47E+11	5.58E+02
Am-242m	2.58E+08	1.11E+04	3.37E+07	1.36E+09	1.70E+10	4.53E+03	6.01E+08	9.22E+08	2.17E+00
Am-243	6.45E+08	3.01E+05	3.52E+08	3.42E+09	4.30E+10	1.64E+05	1.53E+09	2.36E+09	5.35E+00
C-14	4.12E+00	4.12E+00	4.12E+00	4.12E+00	4.12E+00	4.12E+00	4.12E+00	4.12E+00	1.75E-01
Cd-113m	3.95E+04	3.95E+04	3.42E+06	3.95E+04	3.95E+04	3.95E+04	1.56E+06	9.00E+05	2.26E+00
Cl-36	5.46E+00	5.46E+00	4.94E+02	5.46E+00	5.46E+00	5.46E+00	5.81E+00	6.42E+01	2.93E-03
Cm-242	3.78E+06	6.25E+03	1.03E+08	2.58E+07	3.23E+08	6.23E+03	1.62E+07	3.09E+07	1.79E+00
Cm-243	1.90E+08	5.77E+04	1.78E+08	1.08E+09	1.35E+10	3.51E+04	5.29E+08	7.62E+08	2.48E+00
Cm-244	1.51E+10	9.85E+05	1.83E+10	8.88E+10	1.11E+12	9.57E+05	4.53E+10	6.35E+10	2.56E+02
Cm-245	5.04E+06	1.00E+03	2.69E+06	2.68E+07	3.35E+08	5.50E+02	1.19E+07	1.84E+07	4.04E-02
Cm-246	1.79E+06	2.15E+02	9.76E+05	9.55E+06	1.19E+08	1.21E+02	4.26E+06	6.56E+06	1.45E-02
Co-60	7.75E+05	3.00E+06	5.62E+07	2.80E+06	2.20E+06	2.64E+06	5.86E+06	9.62E+06	4.40E+01
Cs-134	3.04E+05	2.53E+05	2.76E+05	2.76E+05	2.57E+05	2.60E+05	3.25E+05	2.93E+05	6.32E+00
Cs-135	6.17E+02	6.17E+02	7.25E+02	6.17E+02	6.17E+02	6.17E+02	6.17E+02	6.30E+02	1.39E-01
Cs-137	4.51E+08	4.03E+08	4.54E+08	4.27E+08	4.08E+08	4.08E+08	4.69E+08	4.44E+08	1.39E+04
Eu-154	7.79E+06	1.03E+07	5.27E+07	7.06E+07	3.48E+08	4.76E+06	7.53E+07	5.15E+07	1.80E+02
Eu-155	2.16E+04	3.73E+04	7.22E+05	8.68E+05	9.22E+06	1.46E+04	6.74E+05	6.81E+05	1.64E+01
Fe-55	7.22E+02	7.02E+02	4.27E+03	7.10E+02	7.06E+02	7.46E+02	1.76E+03	1.46E+03	1.09E+00
H-3	2.53E+03	2.53E+03	2.53E+03	2.53E+03	2.53E+03	2.53E+03	2.53E+03	2.53E+03	3.95E+01
I-129	2.39E+00	5.75E+00	8.63E+00	3.85E+00	3.79E+00	4.29E+04	3.24E+00	1.29E+03	7.43E-03
Kr-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.81E+02
Nb-93m	2.72E+02	7.65E+01	1.13E+05	2.00E+02	4.98E+02	2.00E+01	5.33E+02	1.39E+04	4.74E-01
Nb-94	3.06E+02	1.55E+03	5.18E+04	1.56E+03	1.36E+03	1.54E+03	3.08E+03	7.72E+03	1.87E-02
Ni-59	2.03E+02	1.95E+02	2.23E+03	1.97E+02	1.95E+02	2.12E+02	2.61E+02	4.62E+02	5.03E-01
Ni-63	5.36E+04	5.36E+04	6.67E+05	5.36E+04	5.36E+04	5.36E+04	7.97E+04	1.35E+05	5.87E+01
Np-237	7.55E+06	4.31E+03	4.10E+06	6.68E+07	8.34E+08	3.42E+03	5.97E+06	3.72E+07	6.89E-02
Pa-231	1.57E-01	2.91E-01	3.84E+04	1.48E+04	1.85E+05	2.29E-01	1.09E+01	1.19E+04	1.39E-05
Pb-210	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pd-107	1.03E-02	1.03E-02	2.79E+03	5.57E-02	1.48E-01	1.03E-02	9.52E+00	3.38E+02	2.65E-02
Pm-147	1.21E+00	5.30E+00	1.14E+07	2.37E+05	2.96E+06	2.92E+00	2.30E+05	1.55E+06	3.98E+01
Pu-238	2.25E+10	9.52E+05	6.93E+11	1.26E+11	1.57E+12	8.35E+05	5.93E+10	1.69E+11	5.85E+02
Pu-239	2.38E+09	7.90E+04	6.39E+10	1.30E+10	1.63E+11	7.42E+04	5.98E+09	1.65E+10	5.35E+01
Pu-240	5.06E+09	1.83E+05	1.36E+11	2.77E+10	3.46E+11	1.59E+05	1.27E+10	3.52E+10	1.14E+02
Pu-241	6.92E+09	5.37E+05	7.98E+10	3.59E+10	4.47E+11	2.30E+05	1.51E+10	3.35E+10	6.78E+03
Pu-242	2.15E+07	8.19E+02	5.78E+08	1.18E+08	1.47E+09	6.99E+02	5.39E+07	1.49E+08	5.09E-01
Ra-226	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ra-228	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-106	1.44E+01	1.98E+01	1.15E+04	1.95E+01	1.79E+01	1.91E+01	1.33E+02	1.44E+03	3.00E-03
Sb-125	3.85E+03	4.45E+03	2.32E+05	5.72E+03	1.05E+04	3.46E+03	1.55E+04	3.53E+04	2.89E+00
Se-79	3.52E+01	3.52E+01	5.77E+02	3.52E+01	3.52E+01	3.52E+01	2.22E+02	1.56E+02	1.59E-02
Sm-147	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sm-151	8.04E+00	2.97E+01	6.50E+05	2.19E+06	2.75E+07	2.63E+00	1.50E+06	1.62E+06	5.39E+01
Sn-126	2.33E+03	2.53E+03	7.10E+04	7.94E+03	1.56E+04	2.30E+03	5.64E+03	1.27E+04	1.27E-01
Sr-90	9.32E+07	9.32E+07	1.32E+08	1.19E+10	2.57E+10	9.32E+07	1.19E+08	2.28E+09	9.54E+03
Tc-99	4.72E+02	4.72E+02	1.98E+05	4.72E+02	4.72E+02	1.27E+04	7.41E+03	2.66E+04	3.20E+00
Th-229	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Th-230	3.88E+01	3.88E+01	6.76E+04	1.58E+04	1.96E+05	3.88E+01	1.01E+02	1.59E+04	6.09E-05
Th-232	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-232	2.90E+02	4.57E+02	2.54E+07	8.03E+03	1.23E+05	4.17E+02	1.01E+04	3.06E+06	4.64E-03
U-233	1.13E-01	1.15E-01	1.28E+04	3.12E+00	4.89E+01	1.14E-01	4.56E+00	1.54E+03	1.14E-05
U-234	2.44E+03	2.47E+03	2.75E+08	6.65E+04	1.04E+06	2.44E+03	9.77E+04	3.30E+07	2.49E-01
U-235	2.75E+01	5.21E+01	2.68E+06	6.93E+02	1.02E+04	3.98E+01	9.89E+02	3.22E+05	2.62E-03
U-236	5.81E+02	5.88E+02	6.53E+07	1.58E+04	2.48E+05	5.81E+02	2.76E+02	7.85E+06	6.26E-02
U-238	5.66E+02	6.80E+02	6.22E+07	1.61E+04	2.36E+05	6.38E+02	2.25E+04	7.48E+06	6.32E-02
Zr-93	6.98E+00	1.50E+01	4.13E+03	5.62E+04	6.93E+05	5.57E+00	1.93E+02	2.81E+04	3.38E-01

Nuclide	AVERAGE BWR SUBMERSION DOSE RATE (rem-m^3/FA-s)**										MAR (Curies/FA)
	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Whole Body	Skin	Eye Lens	
H-3	0.00E+00	0.00E+00	4.02E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.84E-05	0.00E+00	0	3.95E+01
Kr-85	1.65E-01	1.89E-01	1.61E-01	1.54E-01	3.10E-01	1.66E-01	1.54E-01	1.68E-01	1.86E+01	0	3.81E+02
Totals:	1.65E-01	1.89E-01	1.61E-01	1.54E-01	3.10E-01	1.66E-01	1.54E-01	1.68E-01	1.86E+01	0.00E+00	

* Inhalation organ doses are cut/pasted from SR Source Terms.xls/Avg PWR/BWR Dose

** Submersion organ doses are cut/pasted from SR Source Terms.xls/Submersion Dose

Inhalation Dose for Maximum PWR Fuel

Nuclide	MAXIMUM PWR INHALATION DOSE (REM/FA)*								MAR (Curies/FA)
	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Whole Body	
Ac-227	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Am-241	1.05E+11	8.60E+06	5.93E+10	5.61E+11	6.99E+12	5.16E+06	2.52E+11	3.86E+11	8.71E+02
Am-242m	1.21E+09	5.21E+04	1.59E+08	6.38E+09	8.00E+10	2.13E+04	2.82E+09	4.33E+09	1.02E+01
Am-243	6.30E+09	2.94E+06	3.44E+09	3.34E+10	4.19E+11	1.60E+06	1.49E+10	2.31E+10	5.22E+01
C-14	1.15E+01	1.15E+01	1.15E+01	1.15E+01	1.15E+01	1.15E+01	1.15E+01	1.15E+01	4.89E-01
Cd-113m	6.67E+05	6.67E+05	5.78E+07	6.67E+05	6.67E+05	6.67E+05	2.63E+07	1.52E+07	3.82E+01
Cl-36	1.81E+01	1.81E+01	1.63E+03	1.81E+01	1.81E+01	1.81E+01	1.92E+01	2.12E+02	9.69E-03
Cm-242	7.23E+07	1.20E+05	1.97E+09	4.95E+08	6.18E+09	1.19E+05	3.11E+08	5.92E+08	3.43E+01
Cm-243	2.93E+09	8.91E+05	2.75E+09	1.67E+10	2.08E+11	5.43E+05	8.16E+09	1.18E+10	3.83E+01
Cm-244	6.59E+11	4.31E+07	8.00E+11	3.89E+12	4.85E+13	4.19E+07	1.98E+12	2.78E+12	1.12E+04
Cm-245	1.76E+08	3.49E+04	9.39E+07	9.34E+08	1.17E+10	1.92E+04	4.15E+08	6.42E+08	1.41E+00
Cm-246	1.04E+08	1.24E+04	5.64E+07	5.52E+08	6.88E+09	7.01E+03	2.46E+08	3.79E+08	8.38E-01
Co-60	9.97E+07	3.85E+08	7.22E+09	3.60E+08	2.83E+08	3.39E+08	7.54E+08	1.24E+09	5.66E+03
Cs-134	1.79E+09	1.49E+09	1.62E+09	1.62E+09	1.51E+09	1.53E+09	1.91E+09	1.73E+09	3.72E+04
Cs-135	2.66E+03	2.66E+03	3.12E+03	2.66E+03	2.66E+03	2.66E+03	2.66E+03	2.72E+03	5.99E-01
Cs-137	3.20E+09	2.86E+09	3.22E+09	3.03E+09	2.90E+09	2.90E+09	3.33E+09	3.15E+09	9.87E+04
Eu-154	2.50E+08	3.31E+08	1.69E+09	2.26E+09	1.12E+10	1.52E+08	2.41E+09	1.65E+09	5.77E+03
Eu-155	2.21E+06	3.82E+06	7.40E+07	8.89E+07	9.45E+08	1.49E+06	6.90E+07	6.98E+07	1.68E+03
Fe-55	4.53E+05	4.40E+05	2.68E+06	4.45E+05	4.43E+05	4.68E+05	1.11E+06	9.14E+05	6.84E+02
H-3	3.02E+04	3.02E+04	3.02E+04	3.02E+04	3.02E+04	3.02E+04	3.02E+04	3.02E+04	4.72E+02
I-129	1.09E+01	2.61E+01	3.93E+01	1.75E+01	1.73E+01	1.95E+05	1.48E+01	5.87E+03	3.38E-02
Kr-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.63E+03
Nb-93m	2.60E+04	7.32E+03	1.08E+07	1.91E+04	4.77E+04	1.91E+03	5.11E+04	1.33E+06	4.54E+01
Nb-94	2.08E+04	1.05E+05	3.51E+06	1.06E+05	9.26E+04	1.04E+05	2.09E+05	5.24E+05	1.27E+00
Ni-59	1.12E+03	1.08E+03	1.23E+04	1.09E+03	1.08E+03	1.17E+03	1.44E+03	2.55E+03	2.78E+00
Ni-63	3.80E+05	3.80E+05	4.73E+06	3.80E+05	3.80E+05	3.80E+05	5.65E+05	9.57E+05	4.16E+02
Np-237	4.22E+07	2.41E+04	2.29E+07	3.73E+08	4.66E+09	1.91E+04	3.33E+07	2.08E+08	3.85E-01
Pa-231	4.81E-01	8.88E-01	1.17E+05	4.53E+04	5.66E+05	7.00E-01	3.33E+01	3.65E+04	4.25E-05
Pb-210	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pd-107	5.63E-02	5.63E-02	1.53E+04	3.05E-01	8.10E-01	5.63E-02	5.21E+01	1.85E+03	1.45E-01
Pm-147	7.14E+02	3.12E+03	6.70E+09	1.39E+08	1.74E+09	1.71E+03	1.35E+08	9.14E+08	2.34E+04
Pu-238	2.37E+11	1.00E+07	7.29E+12	1.32E+12	1.65E+13	8.80E+06	6.25E+11	1.78E+12	6.16E+03
Pu-239	8.21E+09	2.73E+05	2.21E+11	4.50E+10	5.62E+11	2.57E+05	2.07E+10	5.70E+10	1.85E+02
Pu-240	1.73E+10	6.25E+05	4.66E+11	9.48E+10	1.18E+12	5.43E+05	4.36E+10	1.20E+11	3.90E+02
Pu-241	8.08E+10	6.26E+06	9.31E+11	4.19E+11	5.21E+12	2.68E+06	1.76E+11	3.91E+11	7.91E+04
Pu-242	1.27E+08	4.84E+03	3.42E+09	6.96E+08	8.70E+09	4.13E+03	3.19E+08	8.82E+08	3.01E+00
Ra-226	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ra-228	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-106	6.11E+07	8.36E+07	4.89E+10	8.27E+07	7.57E+07	8.08E+07	5.64E+08	6.08E+09	1.27E+04
Sb-125	2.73E+06	3.16E+06	1.65E+08	4.06E+06	7.42E+06	2.46E+06	1.10E+07	2.50E+07	2.05E+03
Se-79	1.54E+02	1.54E+02	2.52E+03	1.54E+02	1.54E+02	1.54E+02	9.69E+02	6.83E+02	6.95E-02
Sm-147	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sm-151	4.67E+01	1.73E+02	3.78E+06	1.27E+07	1.60E+08	1.53E+01	8.70E+06	9.39E+06	3.13E+02
Sn-126	1.15E+04	1.25E+04	3.51E+05	3.93E+04	7.74E+04	1.14E+04	2.79E+04	6.26E+04	6.28E-01
Sr-90	6.15E+08	6.15E+08	8.69E+08	7.83E+10	1.69E+11	6.15E+08	7.83E+08	1.51E+10	6.30E+04
Tc-99	1.89E+03	1.89E+03	7.91E+05	1.89E+03	1.89E+03	5.07E+04	2.96E+04	1.06E+05	1.28E+01
Th-229	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Th-230	2.27E+01	2.27E+01	3.95E+04	9.21E+03	1.15E+05	2.27E+01	5.90E+01	9.32E+03	3.56E-05
Th-232	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-232	3.32E+03	5.23E+03	2.91E+08	9.19E+04	1.40E+06	4.77E+03	1.15E+05	3.50E+07	5.31E-02
U-233	2.41E-01	2.44E-01	2.72E+04	6.62E+00	1.04E+02	2.42E-01	9.67E+00	3.27E+03	2.42E-05
U-234	5.35E+03	5.41E+03	6.02E+08	1.46E+05	2.28E+06	5.35E+03	2.14E+05	7.24E+07	5.46E-01
U-235	4.36E+01	8.25E+01	4.24E+06	1.10E+03	1.61E+04	6.31E+01	1.57E+03	5.10E+05	4.15E-03
U-236	2.08E+03	2.11E+03	2.34E+08	5.66E+04	8.87E+05	2.08E+03	9.86E+02	2.81E+07	2.24E-01
U-238	1.28E+03	1.54E+03	1.41E+08	3.64E+04	5.34E+05	1.44E+03	5.08E+04	1.69E+07	1.43E-01
Zr-93	2.75E+01	5.91E+01	1.62E+04	2.21E+05	2.73E+06	2.19E+01	7.58E+02	1.10E+05	1.33E+00

Nuclide	MAXIMUM PWR SUBMERSION DOSE RATE (rem-m^3/FA-s)**										MAR (Curies/FA)
	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Whole Body	Skin	Eye Lens	
H-3	0.00E+00	0.00E+00	4.80E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.78E-04	0.00E+00	0	4.72E+02
Kr-85	2.44E+00	2.79E+00	2.37E+00	2.27E+00	4.58E+00	2.46E+00	2.27E+00	2.48E+00	2.75E+02	0	5.63E+03
Totals:	2.44E+00	2.79E+00	2.38E+00	2.27E+00	4.58E+00	2.46E+00	2.27E+00	2.48E+00	2.75E+02	0.00E+00	

* Inhalation organ doses are cut/pasted from SR Source Terms.xls/Max PWR/BWR Dose

** Submersion organ doses are cut/pasted from SR Source Terms.xls/Submersion Dose

Inhalation Dose for Maximum BWR Fuel

Nuclide	MAXIMUM BWR INHALATION DOSE (REM/FA)*								MAR (Curies/FA)
	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Whole Body	
Ac-227	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Am-241	3.20E+10	2.63E+06	1.81E+10	1.71E+11	2.14E+12	1.57E+06	7.70E+10	1.18E+11	2.66E+02
Am-242m	4.04E+08	1.74E+04	5.28E+07	2.13E+09	2.67E+10	7.10E+03	9.41E+08	1.44E+09	3.40E+00
Am-243	2.33E+09	1.09E+06	1.27E+09	1.24E+10	1.55E+11	5.92E+05	5.53E+09	8.52E+09	1.93E+01
C-14	7.44E+00	7.44E+00	7.44E+00	7.44E+00	7.44E+00	7.44E+00	7.44E+00	7.44E+00	3.16E-01
Cd-113m	2.43E+05	2.43E+05	2.10E+07	2.43E+05	2.43E+05	2.43E+05	9.57E+06	5.53E+06	1.39E+01
Cl-36	9.31E+00	9.31E+00	8.42E+02	9.31E+00	9.31E+00	9.31E+00	9.90E+00	1.09E+02	4.99E-03
Cm-242	2.38E+07	3.95E+04	6.48E+08	1.63E+08	2.04E+09	3.93E+04	1.02E+08	1.95E+08	1.13E+01
Cm-243	8.58E+08	2.61E+05	8.04E+08	4.89E+09	6.09E+10	1.59E+05	2.39E+09	3.44E+09	1.12E+01
Cm-244	2.32E+11	1.52E+07	2.82E+11	1.37E+12	1.71E+13	1.48E+07	6.99E+11	9.79E+11	3.95E+03
Cm-245	4.41E+07	8.76E+03	2.36E+07	2.34E+08	2.93E+09	4.82E+03	1.04E+08	1.61E+08	3.54E-01
Cm-246	3.67E+07	4.40E+03	2.00E+07	1.96E+08	2.44E+09	2.48E+03	8.73E+07	1.34E+08	2.97E-01
Co-60	1.51E+07	5.83E+07	1.09E+09	5.45E+07	4.28E+07	5.13E+07	1.14E+08	1.87E+08	8.56E+02
Cs-134	5.58E+08	4.64E+08	5.06E+08	5.06E+08	4.72E+08	4.76E+08	5.97E+08	5.38E+08	1.16E+04
Cs-135	1.25E+03	1.25E+03	1.47E+03	1.25E+03	1.25E+03	1.25E+03	1.25E+03	1.28E+03	2.82E-01
Cs-137	1.25E+09	1.12E+09	1.26E+09	1.19E+09	1.14E+09	1.14E+09	1.31E+09	1.24E+09	3.87E+04
Eu-154	7.92E+07	1.05E+08	5.36E+08	7.18E+08	3.54E+09	4.83E+07	7.65E+08	5.23E+08	1.83E+03
Eu-155	8.39E+05	1.45E+06	2.80E+07	3.37E+07	3.58E+08	5.66E+05	2.62E+07	2.64E+07	6.37E+02
Fe-55	1.56E+05	1.51E+05	9.22E+05	1.53E+05	1.52E+05	1.61E+05	3.80E+05	3.14E+05	2.35E+02
H-3	1.13E+04	1.13E+04	1.13E+04	1.13E+04	1.13E+04	1.13E+04	1.13E+04	1.13E+04	1.76E+02
I-129	4.37E+00	1.05E+01	1.58E+01	7.04E+00	6.94E+00	7.85E+04	5.94E+00	2.36E+03	1.36E-02
Kr-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.03E+03
Nb-93m	7.00E+02	1.97E+02	2.91E+05	5.15E+02	1.28E+03	5.15E+01	1.37E+03	3.57E+04	1.22E+00
Nb-94	5.54E+02	2.81E+03	9.38E+04	2.83E+03	2.47E+03	2.78E+03	5.58E+03	1.40E+04	3.39E-02
Ni-59	3.15E+02	3.03E+02	3.46E+03	3.06E+02	3.03E+02	3.29E+02	4.04E+02	7.17E+02	7.80E-01
Ni-63	1.06E+05	1.06E+05	1.32E+06	1.06E+05	1.06E+05	1.06E+05	1.58E+05	2.67E+05	1.16E+02
Np-237	1.46E+07	8.32E+03	7.92E+06	1.29E+08	1.61E+09	6.59E+03	1.15E+07	7.18E+07	1.33E-01
Pa-231	3.33E-01	6.15E-01	8.13E+04	3.13E+04	3.92E+05	4.84E-01	2.31E+01	2.53E+04	2.94E-05
Pb-210	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pd-107	2.21E-02	2.21E-02	6.01E+03	1.20E-01	3.18E-01	2.21E-02	2.05E+01	7.27E+02	5.70E-02
Pm-147	2.28E+02	9.94E+02	2.14E+09	4.44E+07	5.55E+08	5.47E+02	4.31E+07	2.91E+08	7.46E+03
Pu-238	8.12E+10	3.44E+06	2.50E+12	4.53E+11	5.66E+12	3.01E+06	2.14E+11	6.08E+11	2.11E+03
Pu-239	2.38E+09	7.91E+04	6.41E+10	1.30E+10	1.63E+11	7.44E+04	5.99E+09	1.65E+10	5.36E+01
Pu-240	6.57E+09	2.37E+05	1.77E+11	3.60E+10	4.50E+11	2.06E+05	1.65E+10	4.56E+10	1.48E+02
Pu-241	2.30E+10	1.78E+06	2.65E+11	1.19E+11	1.48E+12	7.62E+05	5.01E+10	1.11E+11	2.25E+04
Pu-242	5.31E+07	2.03E+03	1.43E+09	2.91E+08	3.64E+09	1.73E+03	1.33E+08	3.69E+08	1.26E+00
Ra-226	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ra-228	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-106	1.58E+07	2.17E+07	1.27E+10	2.14E+07	1.96E+07	2.09E+07	1.46E+08	1.57E+09	3.29E+03
Sb-125	8.27E+05	9.56E+05	4.99E+07	1.23E+06	2.25E+06	7.44E+05	3.33E+06	7.58E+06	6.21E+02
Se-79	6.39E+01	6.39E+01	1.05E+03	6.39E+01	6.39E+01	6.39E+01	4.03E+02	2.84E+02	2.89E-02
Sm-147	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sm-151	1.23E+01	4.53E+01	9.91E+05	3.35E+06	4.20E+07	4.01E+00	2.28E+06	2.46E+06	8.22E+01
Sn-126	4.62E+03	5.03E+03	1.41E+05	1.58E+04	3.10E+04	4.57E+03	1.12E+04	2.51E+04	2.52E-01
Sr-90	2.46E+08	2.46E+08	3.48E+08	3.13E+10	6.78E+10	2.46E+08	3.13E+08	6.03E+09	2.52E+04
Tc-99	7.90E+02	7.90E+02	3.31E+05	7.90E+02	7.90E+02	2.12E+04	1.24E+04	4.45E+04	5.35E+00
Th-229	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Th-230	1.30E+01	1.30E+01	2.28E+04	5.30E+03	6.61E+04	1.30E+01	3.40E+01	5.36E+03	2.05E-05
Th-232	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-232	1.25E+03	1.97E+03	1.10E+08	3.46E+04	5.28E+05	1.80E+03	4.34E+04	1.32E+07	2.00E-02
U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-234	2.22E+03	2.24E+03	2.49E+08	6.04E+04	9.45E+05	2.22E+03	8.86E+04	3.00E+07	2.26E-01
U-235	9.88E+00	1.87E+01	9.60E+05	2.49E+02	3.65E+03	1.43E+01	3.55E+02	1.15E+05	9.40E-04
U-236	8.87E+02	8.98E+02	9.96E+07	2.41E+04	3.78E+05	8.87E+02	4.20E+02	1.20E+07	9.55E-02
U-238	5.44E+02	6.54E+02	5.97E+07	1.55E+04	2.27E+05	6.13E+02	2.16E+04	7.18E+06	6.07E-02
Zr-93	1.24E+01	2.68E+01	7.36E+03	1.00E+05	1.24E+06	9.93E+00	3.44E+02	5.01E+04	6.03E-01

Nuclide	MAXIMUM BWR SUBMERSION DOSE RATE (rem-m^3/FA-s)**										MAR (Curies/FA)
	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Whole Body	Skin	Eye Lens	
H-3	0.00E+00	0.00E+00	1.79E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.16E-04	0.00E+00	0	1.76E+02
Kr-85	8.79E-01	1.01E+00	8.56E-01	8.19E-01	1.65E+00	8.86E-01	8.19E-01	8.94E-01	9.91E+01	0	2.03E+03
Totals:	8.79E-01	1.01E+00	8.58E-01	8.19E-01	1.65E+00	8.86E-01	8.19E-01	8.94E-01	9.91E+01	0.00E+00	

* Inhalation organ doses are cut/pasted from SR Source Terms.xls/Max PWR/BWR Dose

** Submersion organ doses are cut/pasted from SR Source Terms.xls/Submersion Dose

Crud Calculations

Fe-55 Included In Crud Calc. (Y/N):	Y	
Crud Decay Time (years):	25	
Fe-55 PWR Surface Activity (uCi/cm^2) =	10.3	{values are corrected for half-life & avg surface activity if #
Fe-55 BWR Surface Activity (uCi/cm^2) =	13.0	FA>1 (CRWMS M&O 1999d, Table 8-2)}
Co-60 PWR Surface Activity (uCi/cm^2) =	2.6	
Co-60 BWR Surface Activity (uCi/cm^2) =	23.4	
Bounding PWR Surface Area (cm^2) =	449,003	(CRWMS M&O 1999h, p. 25)
Bounding BWR Surface Area (cm^2) =	168,148	(CRWMS M&O 1999b, p. 46)

Conversions		Co-60 Half Life	Fe-55 Half Life
Bq per uCi =	3.70E+04	5.271 y	2.73 y
rem per Sv =	100		

Crud Source (Ci/FA)	
Fe-55 PWR	4.6
Fe-55 BWR	2.2
Co-60 PWR	1.2
Co-60 BWR	3.9

Dose Conversion Factors for Co-60 & Fe-55 (Sv/Bq)

	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Whole Body
Co-60	4.76E-09	1.84E-08	3.45E-07	1.72E-08	1.35E-08	1.62E-08	3.60E-08	5.91E-08
Fe-55	1.79E-10	1.74E-10	1.06E-09	1.76E-10	1.75E-10	1.85E-10	4.37E-10	3.61E-10

Crud Inhalation Dose (rem/FA)

	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Whole Body
PWR Co-60	2.07E+04	7.99E+04	1.50E+06	7.47E+04	5.86E+04	7.04E+04	1.56E+05	2.57E+05
PWR Fe-55	3.07E+03	2.99E+03	1.82E+04	3.02E+03	3.00E+03	3.18E+03	7.50E+03	6.20E+03
BWR Co-60	6.93E+04	2.68E+05	5.03E+06	2.51E+05	1.97E+05	2.36E+05	5.24E+05	8.61E+05
BWR Fe-55	1.45E+03	1.41E+03	8.56E+03	1.42E+03	1.41E+03	1.49E+03	3.53E+03	2.92E+03

Source Term Groupings

Group	Nuclide	Average PWR Inhalation Dose (rem/FA)							
		Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Whole Body
cs	Cs-134	1.21E+06	1.01E+06	1.10E+06	1.10E+06	1.03E+06	1.03E+06	1.30E+06	1.17E+06
cs	Cs-135	1.55E+03	1.55E+03	1.83E+03	1.55E+03	1.55E+03	1.55E+03	1.55E+03	1.59E+03
cs	Cs-137	1.33E+09	1.19E+09	1.34E+09	1.26E+09	1.21E+09	1.21E+09	1.39E+09	1.31E+09
g	H-3	7.30E+03	7.30E+03	7.30E+03	7.30E+03	7.30E+03	7.30E+03	7.30E+03	7.30E+03
g	I-129	7.07E+00	1.70E+01	2.56E+01	1.14E+01	1.12E+01	1.27E+05	9.61E+00	3.82E+03
g	Kr-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
p	Ac-227	2.12E+03	6.31E-01	9.17E+04	1.39E+04	1.73E+05	3.85E-01	7.98E+03	2.08E+04
p	Am-241	2.38E+11	1.96E+07	1.35E+11	1.27E+12	1.59E+13	1.17E+07	5.73E+11	8.77E+11
p	Am-242m	7.59E+08	3.26E+04	9.93E+07	4.00E+09	5.01E+10	1.33E+04	1.77E+09	2.72E+09
p	Am-243	2.65E+09	1.24E+06	1.45E+09	1.41E+10	1.77E+11	6.75E+05	6.30E+09	9.72E+09
p	C-14	7.81E+00	7.81E+00	7.81E+00	7.81E+00	7.81E+00	7.81E+00	7.81E+00	7.81E+00
p	Cd-113m	1.34E+05	1.34E+05	1.16E+07	1.34E+05	1.34E+05	1.34E+05	5.27E+06	3.05E+06
p	Cl-36	1.27E+01	1.27E+01	1.15E+03	1.27E+01	1.27E+01	1.27E+01	1.35E+01	1.49E+02
p	Cm-242	1.11E+07	1.84E+04	3.02E+08	7.60E+07	9.50E+08	1.83E+04	4.78E+07	9.10E+07
p	Cm-243	7.89E+08	2.40E+05	7.39E+08	4.50E+09	5.60E+10	1.46E+05	2.20E+09	3.16E+09
p	Cm-244	8.00E+10	5.23E+06	9.71E+10	4.72E+11	5.89E+12	5.08E+06	2.41E+11	3.37E+11
p	Cm-245	3.83E+07	7.60E+03	2.04E+07	2.03E+08	2.54E+09	4.18E+03	9.04E+07	1.40E+08
p	Cm-246	1.29E+07	1.54E+03	7.00E+06	6.85E+07	8.54E+08	8.70E+02	3.06E+07	4.71E+07
p	Co-60	5.51E+06	2.13E+07	4.00E+08	1.99E+07	1.56E+07	1.88E+07	4.17E+07	6.84E+07
p	Eu-154	2.90E+07	3.85E+07	1.97E+08	2.63E+08	1.30E+09	1.77E+07	2.81E+08	1.92E+08
p	Eu-155	6.80E+04	1.17E+05	2.27E+06	2.73E+06	2.90E+07	4.58E+04	2.12E+06	2.14E+06
p	Fe-55	2.30E+03	2.23E+03	1.36E+04	2.26E+03	2.25E+03	2.38E+03	5.61E+03	4.64E+03
p	Nb-93m	7.46E+03	2.10E+03	3.10E+06	5.48E+03	1.37E+04	5.48E+02	1.46E+04	3.80E+05
p	Nb-94	1.37E+04	6.95E+04	2.32E+06	7.02E+04	6.12E+04	6.89E+04	1.38E+05	3.46E+05
p	Ni-59	8.43E+02	8.12E+02	9.28E+03	8.20E+02	8.12E+02	8.82E+02	1.08E+03	1.92E+03
p	Ni-63	2.30E+05	2.30E+05	2.86E+06	2.30E+05	2.30E+05	2.30E+05	3.42E+05	5.80E+05
p	Np-237	2.71E+07	1.54E+04	1.47E+07	2.39E+08	2.99E+09	1.22E+04	2.14E+07	1.33E+08
p	Pa-231	3.36E-01	6.21E-01	8.21E+04	3.16E+04	3.96E+05	4.89E-01	2.33E+01	2.55E+04
p	Pb-210	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
p	Pd-107	3.27E-02	3.27E-02	8.87E+03	1.77E-01	4.70E-01	3.27E-02	3.02E+01	1.07E+03
p	Pm-147	3.63E+00	1.59E+01	3.41E+07	7.09E+05	8.85E+06	8.72E+00	6.87E+05	4.65E+06
p	Pu-238	8.81E+10	3.73E+06	2.71E+12	4.91E+11	6.14E+12	3.27E+06	2.32E+11	6.60E+11
p	Pu-239	7.86E+09	2.61E+05	2.12E+11	4.30E+10	5.38E+11	2.46E+05	1.98E+10	5.46E+10
p	Pu-240	1.41E+10	5.09E+05	3.80E+11	7.73E+10	9.66E+11	4.42E+05	3.55E+10	9.81E+10
p	Pu-241	2.52E+10	1.96E+06	2.91E+11	1.31E+11	1.63E+12	8.36E+05	5.50E+10	1.22E+11
p	Pu-242	6.92E+07	2.64E+03	1.86E+09	3.79E+08	4.74E+09	2.25E+03	1.74E+08	4.81E+08
p	Ra-226	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
p	Ra-228	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
p	Ru-106	5.92E+01	8.10E+01	4.73E+04	8.01E+01	7.33E+01	7.83E+01	5.46E+02	5.88E+03
p	Sb-125	1.29E+04	1.49E+04	7.80E+05	1.92E+04	3.51E+04	1.16E+04	5.21E+04	1.19E+05
p	Se-79	1.01E+02	1.01E+02	1.66E+03	1.01E+02	1.01E+02	1.01E+02	6.37E+02	4.49E+02
p	Sm-147	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
p	Sm-151	3.15E+01	1.16E+02	2.55E+06	8.59E+06	1.08E+08	1.03E+01	5.86E+06	6.33E+06
p	Sn-126	7.05E+03	7.68E+03	2.15E+05	2.41E+04	4.74E+04	6.98E+03	1.71E+04	3.84E+04
p	Tc-99	1.33E+03	1.33E+03	5.55E+05	1.33E+03	1.33E+03	3.56E+04	2.08E+04	7.47E+04
p	Th-229	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
p	Th-230	9.42E+01	9.42E+01	1.64E+05	3.83E+04	4.77E+05	9.42E+01	2.45E+02	3.87E+04
p	Th-232	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
p	U-232	1.28E+03	2.02E+03	1.12E+08	3.55E+04	5.42E+05	1.84E+03	4.44E+04	1.35E+07
p	U-233	4.05E-01	4.11E-01	4.58E+04	1.11E+01	1.75E+02	4.07E-01	1.63E+01	5.51E+03
p	U-234	6.64E+03	6.71E+03	7.46E+08	1.81E+05	2.83E+06	6.64E+03	2.66E+05	8.98E+07
p	U-235	7.73E+01	1.46E+02	7.52E+06	1.95E+03	2.86E+04	1.12E+02	2.78E+03	9.04E+05
p	U-236	1.60E+03	1.62E+03	1.79E+08	4.35E+04	6.81E+05	1.60E+03	7.57E+02	2.16E+07
p	U-238	1.33E+03	1.59E+03	1.46E+08	3.77E+04	5.53E+05	1.49E+03	5.26E+04	1.75E+07
p	Zr-93	1.85E+01	3.97E+01	1.09E+04	1.49E+05	1.83E+06	1.47E+01	5.09E+02	7.43E+04
sr	Sr-90	2.66E+08	2.66E+08	3.75E+08	3.38E+10	7.32E+10	2.66E+08	3.38E+08	6.51E+09

Grouped Source Term - Average PWR

Group	Description	Inhalation Dose (rem/FA)							
		Gonad	Breast	Lung	R. Marrow	B. Surface	Thyroid	Remainder	Whole Body
p	Particulates	4.58E+11	9.32E+07	3.83E+12	2.51E+12	3.14E+13	5.95E+07	1.17E+12	2.17E+12
g	Noble Gases	7.30E+03	7.31E+03	7.32E+03	7.31E+03	7.31E+03	1.34E+05	7.31E+03	1.11E+04
cs	Cesium	1.33E+09	1.19E+09	1.34E+09	1.26E+09	1.21E+09	1.21E+09	1.39E+09	1.31E+09
sr	Strontium	2.66E+08	2.66E+08	3.75E+08	3.38E+10	7.32E+10	2.66E+08	3.38E+08	6.51E+09
c	Crud	2.37E+04	8.29E+04	1.52E+06	7.77E+04	6.16E+04	7.35E+04	1.64E+05	2.63E+05

CSNF Release Fractions in Air

Notes:	(1)	(2)	(3)	(4)	(5)	(6)
Nuclide	Cladding Damage Fraction (DF)	Airborne Release Fraction (ARF)	Local Dep. (DEP)	Clad Release Fraction (CR)	Respirable Fraction (RF)	Effective Release Fraction
H-3	1.0	0.3	1.0	1.0	1.0	3.00E-01
Kr-85	1.0	0.3	1.0	1.0	1.0	3.00E-01
I-129	1.0	0.3	1.0	1.0	1.0	3.00E-01
Cs	1.0	2.0E-04	1.0	1.0	1.0	2.00E-04
Sr	1.0	3.0E-05	1.0	1.0	5.0E-03	1.50E-07
Ru	1.0	3.0E-05	1.0	1.0	5.0E-03	1.50E-07
Crud	1.0	1.0E+00	1.0	1.0	3.0E-01	3.00E-01
Particulates	1.0	3.0E-05	1.0	1.0	5.0E-03	1.50E-07

CSNF Release Fractions in Water (Assumption 3.21)

Notes:	(1)	(2)	(3)	(4)	(5)	(6)
Nuclide	Cladding Damage Fraction (DF)	Airborne Release Fraction (ARF)	Local Dep. (DEP)	Clad Release Fraction (CR)	Respirable Fraction (RF)	Effective Release Fraction
H-3	1.0	0.3	1.0	1.0	1.0	0.3
Kr-85	1.0	0.3	1.0	1.0	1.0	0.3
I-129	1.0	0.3	1.0	1.0	1.0	0.3
Cs	1.0	0.0	1.0	1.0	1.0	0
Sr	1.0	0.0	1.0	1.0	1.0	0
Ru	1.0	0.0	1.0	1.0	1.0	0
Crud	1.0	0.0	1.0	1.0	1.0	0
Particulates	1.0	0.0	1.0	1.0	1.0	0

Notes:

(1) A fraction of 1.0 indicates that all the cladding is failed.

(2) ARFs in air are taken from Table 8-1 of CRWMS M&O (1999d); ARFs in water are based on Assumption 3.21.

(3) A factor of 1.0 indicates no local deposition.

(4) A factor of 1.0 indicates no retention by the cladding.

(5) Respirable fractions are conservatively taken to be 1.0 for inhalation and ingestion (Assumption 3.24).

(6) Effective release fractions are obtained by multiplying columns (1) through (5)

X/Q Values

Distance (meters)	X/Q Values, s/m^3			
	Max Sector Chronic	95% Overall	50% Acute	99.5% Acute
5,000	5.74E-07	2.47E-05	1.17E-05	4.68E-05
8,000	2.98E-07	1.55E-05	6.89E-06	2.94E-05
11,000	1.99E-07	1.15E-05	4.92E-06	2.17E-05
100	4.77E-04	5.18E-03	3.02E-03	9.83E-03

Submersion Dose (Due to Noble Gases H-3 and Kr-85)

Event: 1-11 Basket Drop Onto Another Basket in Dryer

Fuel Type: Average PWR

(Column No.)	**Average PWR Submersion Dose Rate (rem-m^3/FA-s)** (1)	# of FA's (2)	Release Fraction (3)	Mitigation Factor (4)	100-m X/Q (sec/m^3) (5)	100-m Non-Involved Worker Dose (rem) =(1)*(2)*(3)*(4)*(5)
Gonad	4.89E-01	8	3.00E-01	1.00E+00	4.77E-04	5.60E-04
Breast	5.60E-01	8	3.00E-01	1.00E+00	4.77E-04	6.41E-04
Lung	4.78E-01	8	3.00E-01	1.00E+00	4.77E-04	5.47E-04
R Marrow	4.56E-01	8	3.00E-01	1.00E+00	4.77E-04	5.22E-04
B Surface	9.20E-01	8	3.00E-01	1.00E+00	4.77E-04	1.05E-03
Thyroid	4.93E-01	8	3.00E-01	1.00E+00	4.77E-04	5.65E-04
Remainder	4.56E-01	8	3.00E-01	1.00E+00	4.77E-04	5.22E-04
Whole Body	4.98E-01	8	3.00E-01	1.00E+00	4.77E-04	5.70E-04
Skin	5.52E+01	8	3.00E-01	1.00E+00	4.77E-04	6.32E-02
Eye Lens	0.00E+00	8	3.00E-01	1.00E+00	4.77E-04	0.00E+00

Inhalation Dose to the Gonad

Event: 1-11 Basket Drop Onto Another Basket in Dryer
Fuel Type: Average PWR

Group	Source Term (rem/FA)	# of FA's	Release Fraction	Mitigation Factor	Breathing Rate (m^3/sec)	100-m X/Q (sec/m^3)	100-m Non-Involved Worker Dose (rem)	% of Total
Particulates	4.58E+11	8	1.50E-07	1.0E-02	3.30E-04	4.77E-04	8.65E-04	0.25
Noble Gas	7.30E+03	8	3.00E-01	1.0E+00	3.30E-04	4.77E-04	2.76E-03	0.81
Cesium	1.33E+09	8	2.00E-04	1.0E+00	3.30E-04	4.77E-04	3.36E-01	98.91
Strontium	2.66E+08	8	1.50E-07	1.0E-02	3.30E-04	4.77E-04	5.02E-07	0.00
Crud	2.37E+04	8	3.00E-01	1.0E-02	3.30E-04	4.77E-04	8.97E-05	0.03
						Total:	3.40E-01	100.00

Inhalation Dose to the Breast

Event: 1-11 Basket Drop Onto Another Basket in Dryer
Fuel Type: Average PWR

Group	Source Term (rem/FA)	# of FA's	Release Fraction	Mitigation Factor	Breathing Rate (m^3/sec)	100-m X/Q (sec/m^3)	100-m Non-Involved Worker Dose (rem)	% of Total
Particulates	9.32E+07	8	1.50E-07	1.0E-02	3.30E-04	4.77E-04	1.76E-07	0.00
Noble Gas	7.31E+03	8	3.00E-01	1.0E+00	3.30E-04	4.77E-04	2.76E-03	0.91
Cesium	1.19E+09	8	2.00E-04	1.0E+00	3.30E-04	4.77E-04	3.01E-01	98.99
Strontium	2.66E+08	8	1.50E-07	1.0E-02	3.30E-04	4.77E-04	5.02E-07	0.00
Crud	8.29E+04	8	3.00E-01	1.0E-02	3.30E-04	4.77E-04	3.13E-04	0.10
						Total:	3.04E-01	100.00

Inhalation Dose to the Lung

Event: 1-11 Basket Drop Onto Another Basket in Dryer
Fuel Type: Average PWR

Group	Source Term (rem/FA)	# of FA's	Release Fraction	Mitigation Factor	Breathing Rate (m^3/sec)	100-m X/Q (sec/m^3)	100-m Non-Involved Worker Dose (rem)	% of Total
Particulates	3.83E+12	8	1.50E-07	1.0E-02	3.30E-04	4.77E-04	7.24E-03	2.05
Noble Gas	7.32E+03	8	3.00E-01	1.0E+00	3.30E-04	4.77E-04	2.77E-03	0.78
Cesium	1.34E+09	8	2.00E-04	1.0E+00	3.30E-04	4.77E-04	3.38E-01	95.55
Strontium	3.75E+08	8	1.50E-07	1.0E-02	3.30E-04	4.77E-04	7.09E-07	0.00
Crud	1.52E+06	8	3.00E-01	1.0E-02	3.30E-04	4.77E-04	5.73E-03	1.62
						Total:	3.54E-01	100.00

Inhalation Dose to the R Marrow

Event: 1-11 Basket Drop Onto Another Basket in Dryer
Fuel Type: Average PWR

Group	Source Term (rem/FA)	# of FA's	Release Fraction	Mitigation Factor	Breathing Rate (m^3/sec)	100-m X/Q (sec/m^3)	100-m Non-Involved Worker Dose (rem)	% of Total
Particulates	2.51E+12	8	1.50E-07	1.0E-02	3.30E-04	4.77E-04	4.75E-03	1.46
Noble Gas	7.31E+03	8	3.00E-01	1.0E+00	3.30E-04	4.77E-04	2.76E-03	0.85
Cesium	1.26E+09	8	2.00E-04	1.0E+00	3.30E-04	4.77E-04	3.18E-01	97.59
Strontium	3.38E+10	8	1.50E-07	1.0E-02	3.30E-04	4.77E-04	6.39E-05	0.02
Crud	7.77E+04	8	3.00E-01	1.0E-02	3.30E-04	4.77E-04	2.94E-04	0.09
					Total		3.26E-01	100.00

Inhalation Dose to the Bone Surface

Event: 1-11 Basket Drop Onto Another Basket in Dryer
Fuel Type: Average PWR

Group	Source Term (rem/FA)	# of FA's	Release Fraction	Mitigation Factor	Breathing Rate (m^3/sec)	100-m X/Q (sec/m^3)	100-m Non-Involved Worker Dose (rem)	% of Total
Particulates	3.14E+13	8	1.50E-07	1.0E-02	3.30E-04	4.77E-04	5.92E-02	16.15
Noble Gas	7.31E+03	8	3.00E-01	1.0E+00	3.30E-04	4.77E-04	2.76E-03	0.75
Cesium	1.21E+09	8	2.00E-04	1.0E+00	3.30E-04	4.77E-04	3.04E-01	83.00
Strontium	7.32E+10	8	1.50E-07	1.0E-02	3.30E-04	4.77E-04	1.38E-04	0.04
Crud	6.16E+04	8	3.00E-01	1.0E-02	3.30E-04	4.77E-04	2.33E-04	0.06
					Total		3.67E-01	100.00

Inhalation Dose to the Thyroid

Event: 1-11 Basket Drop Onto Another Basket in Dryer
Fuel Type: Average PWR

Group	Source Term (rem/FA)	# of FA's	Release Fraction	Mitigation Factor	Breathing Rate (m^3/sec)	100-m X/Q (sec/m^3)	100-m Non-Involved Worker Dose (rem)	% of Total
Particulates	5.95E+07	8	1.50E-07	1.0E-02	3.30E-04	4.77E-04	1.12E-07	0.00
Noble Gas	1.34E+05	8	3.00E-01	1.0E+00	3.30E-04	4.77E-04	5.07E-02	14.29
Cesium	1.21E+09	8	2.00E-04	1.0E+00	3.30E-04	4.77E-04	3.04E-01	85.63
Strontium	2.66E+08	8	1.50E-07	1.0E-02	3.30E-04	4.77E-04	5.02E-07	0.00
Crud	7.35E+04	8	3.00E-01	1.0E-02	3.30E-04	4.77E-04	2.78E-04	0.08
					Total		3.55E-01	100.00

Inhalation Dose to the Remainder

Event: 1-11 Basket Drop Onto Another Basket in Dryer
Fuel Type: Average PWR

Group	Source Term (rem/FA)	# of FA's	Release Fraction	Mitigation Factor	Breathing Rate (m^3/sec)	100-m X/Q (sec/m^3)	100-m Non-Involved Worker Dose (rem)	% of Total
Particulates	1.17E+12	8	1.50E-07	1.0E-02	3.30E-04	4.77E-04	2.20E-03	0.62
Noble Gas	7.31E+03	8	3.00E-01	1.0E+00	3.30E-04	4.77E-04	2.76E-03	0.78
Cesium	1.39E+09	8	2.00E-04	1.0E+00	3.30E-04	4.77E-04	3.50E-01	98.43
Strontium	3.38E+08	8	1.50E-07	1.0E-02	3.30E-04	4.77E-04	6.39E-07	0.00
Crud	1.64E+05	8	3.00E-01	1.0E-02	3.30E-04	4.77E-04	6.19E-04	0.17
					Total		3.55E-01	100.00

Inhalation Dose to the Whole Body

Event: 1-11 Basket Drop Onto Another Basket in Dryer
Fuel Type: Average PWR

Group	Source Term (rem/FA)	# of FA's	Release Fraction	Mitigation Factor	Breathing Rate (m^3/sec)	100-m X/Q (sec/m^3)	100-m Non-Involved Worker Dose (rem)	% of Total
Particulates	2.17E+12	8	1.50E-07	1.0E-02	3.30E-04	4.77E-04	4.09E-03	32.46
Noble Gas	1.11E+04	8	3.00E-01	1.0E+00	3.30E-04	4.77E-04	4.20E-03	33.32
Cesium	1.31E+09	8	2.00E-04	1.0E-02	3.30E-04	4.77E-04	3.31E-03	26.25
Strontium	6.51E+09	8	1.50E-07	1.0E-02	3.30E-04	4.77E-04	1.23E-05	0.10
Crud	2.63E+05	8	3.00E-01	1.0E-02	3.30E-04	4.77E-04	9.93E-04	7.88
					Total		1.26E-02	100.00

Annual Worker Dose with HEPAs and Chronic X/Q

Category 1 DBE	HEPA Mitigated Annual Doses (rem/yr)			
	TEDE	Max.CDE+DDE	Eye	Skin
1-01	2.79E-04	3.00E-03	0.00E+00	3.70E-03
1-02	2.33E-05	2.50E-04	0.00E+00	3.08E-04
1-03	2.51E-05	2.70E-04	0.00E+00	3.33E-04
1-04	2.29E-04	2.46E-03	0.00E+00	3.03E-03
1-05	1.96E-04	2.10E-03	0.00E+00	2.59E-03
1-06	1.96E-04	2.10E-03	0.00E+00	2.59E-03
1-07	1.96E-04	2.10E-03	0.00E+00	2.59E-03
1-08	9.78E-05	1.05E-03	0.00E+00	1.30E-03
1-09	9.78E-05	1.05E-03	0.00E+00	1.30E-03
1-10	2.70E-04	7.53E-03	0.00E+00	1.30E-03
1-11	5.40E-04	1.51E-02	0.00E+00	2.59E-03
1-12	7.72E-04	2.15E-02	0.00E+00	3.70E-03
1-13	4.14E-04	1.08E-02	0.00E+00	1.85E-03
1-14	7.72E-04	2.15E-02	0.00E+00	3.70E-03
Routine Surface	8.42E-04 (7)	8.42E-04 (7)	0.00E+00	9.34E-02
Routine Subsurface	6.57E-04 (7)	6.57E-04 (7)	0.00E+00	1.02E-02
Total (rem/yr):	4.11E-03	9.08E-02	0.00E+00	1.35E-01
Reg. Limit (rem/yr):	5.00	50.00	15.00	50.00
Safety Factor:	1217	551	N/A	372

Assumptions:

1. Average PWR Fuel
2. 100 meter distance
3. Max Sector Chronic Chi/Q
4. Includes HEPA Mitigation
5. Only noble gases released from pool
6. Cs Mitigated by HEPAs
7. Effective and organ inhalation doses (CEDE and CDE) from subsurface particulates are negligible, therefore, only DDE contribution is considered. This is based on examination of GENII-S results for Run PRCHSB in Attachment IV, Table 6.

Input Parameters for Category 1 Dose Calculations:

Fuel Type:	Average PWR (Note 1)	
Event Description:	SFA Drop Onto Another SFA in Cask	
Event #:	1-01	
Location:	Cask Unloading Pool	
Event Frequency:	2.34E-01	
Number of Fuel Assemblies Damaged:	2	(Note 1)
Does the Event Occur in a Pool?	Yes	
HEPA Mitigation Factor:	0.01	Particulate Release (Note 3)
	1.00	Gaseous Release (Note 3)
X/Q Value: Distance (m): 100 / 99.5% Acute	4.77E-04	(Note 2)
Breathing Rate (m^3/sec)	3.30E-04	(Note 4)
Ground Release?	Y	(Note 5)

Note 1: Average PWR fuel is used for all Category 1 event releases because it results in larger worker doses than Average BWR fuel.

Note 2: Chi/Q value for worker dose is based on chronic releases and 100-m distance to the receptor.

Note 3: HEPA filters, if available, are 99% effective in retaining particulates and volatiles (Cs) (Assumption 3.23). 100% of the Noble gases are released.

Note 4: Breathing rate for workers is based on recommended value in NUREG-1536 (NRC 1997).

Note 5: Ground releases are conservatively assumed for Cat. 1 events; using a stack release will typically result in a lower dose at 100-m (Assumption 3.25).

Blue shading = calculated fields

Yellow shading = input fields

Input Parameters for Category 1 Dose Calculations:

Fuel Type:		
Average PWR / Average BWR / Maximum PWR / Maximum BWR	Average PWR (Note 1)	
Event Description:		
SFA Collision		
Event #:	1-02	
Location:	Cask Unloading Pool	
Event Frequency:	3.90E-02	
Number of Fuel Assemblies Damaged:	1	(Note 1)
Does the Event Occur in a Pool?	Yes / No	
HEPA Mitigation Factor:		
HEPA Filtration	0.01	Particulate Release (Note 3)
No HEPA Filtration	1.00	Gaseous Release (Note 3)
X/Q Value:		
Distance (m): 100 / 5,000 / 8,000 / 11,000	99.5% Acute / 50% Acute / 95% Overall Site / Max Sector Chronic	4.77E-04 (Note 2)
Breathing Rate (m^3/sec)	3.30E-04	(Note 4)
Ground Release?	Y	(Note 5)

Note 1: Average PWR fuel is used for all Category 1 event releases because it results in larger worker doses than Average BWR fuel.

Note 2: Chi/Q value for worker dose is based on chronic releases and 100-m distance to the receptor.

Note 3: HEPA filters, if available, are 99% effective in retaining particulates and volatiles (Cs) (Assumption 3.23). 100% of the Noble gases are released.

Note 4: Breathing rate for workers is based on recommended value in NUREG-1536 (NRC 1997).

Note 5: Ground releases are conservatively assumed for Cat. 1 events; using a stack release will typically result in a lower dose at 100-m (Assumption 3.25).

Blue shading = calculated fields

Yellow shading = input fields

Input Parameters for Category 1 Dose Calculations:

Fuel Type:		
Average PWR / Average BWR / Maximum PWR / Maximum BWR	Average PWR (Note 1)	
Event Description:		
SFA Drop Onto Empty Basket		
Event #:	1-03	
Location:	Cask Unloading Pool	
Event Frequency:	4.22E-02	
Number of Fuel Assemblies Damaged:	1	(Note 1)
Does the Event Occur in a Pool?	Yes / No	
HEPA Mitigation Factor:		
HEPA Filtration	0.01	Particulate Release (Note 3)
No HEPA Filtration	1.00	Gaseous Release (Note 3)
X/Q Value:		
Distance (m): 100 / 5,000 / 8,000 / 11,000	99.5% Acute / 50% Acute / 95% Overall Site / Max Sector Chronic	4.77E-04 (Note 2)
Breathing Rate (m^3/sec)	3.30E-04	(Note 4)
Ground Release?	Y	(Note 5)

Note 1: Average PWR fuel is used for all Category 1 event releases because it results in larger worker doses than Average BWR fuel.

Note 2: Chi/Q value for worker dose is based on chronic releases and 100-m distance to the receptor.

Note 3: HEPA filters, if available, are 99% effective in retaining particulates and volatiles (Cs) (Assumption 3.23). 100% of the Noble gases are released.

Note 4: Breathing rate for workers is based on recommended value in NUREG-1536 (NRC 1997).

Note 5: Ground releases are conservatively assumed for Cat. 1 events; using a stack release will typically result in a lower dose at 100-m (Assumption 3.25).

Blue shading = calculated fields

Yellow shading = input fields

Input Parameters for Category 1 Dose Calculations:

Fuel Type:		
Average PWR / Average BWR / Maximum PWR / Maximum BWR	Average PWR	(Note 1)
Event Description:		
SFA Drop Onto Another SFA in Basket Staging Rack (Lowering Into)		
Event #:	1-04	
Location:	Cask Unloading Pool	
Event Frequency:	1.92E-01	
Number of Fuel Assemblies Damaged:	2	(Note 1)
Does the Event Occur in a Pool?	Yes / No	
HEPA Mitigation Factor:		
HEPA Filtration	0.01	Particulate Release (Note 3)
No HEPA Filtration	1.00	Gaseous Release (Note 3)
X/Q Value:		
Distance (m): 100 / 5,000 / 8,000 / 11,000		
99.5% Acute / 50% Acute / 95% Overall Site / Max Sector Chronic	4.77E-04	(Note 2)
Breathing Rate (m^3/sec)	3.30E-04	(Note 4)
Ground Release?	Y	(Note 5)

Note 1: Average PWR fuel is used for all Category 1 event releases because it results in larger worker doses than Average BWR fuel.

Note 2: Chi/Q value for worker dose is based on chronic releases and 100-m distance to the receptor.

Note 3: HEPA filters, if available, are 99% effective in retaining particulates and volatiles (Cs) (Assumption 3.23). 100% of the Noble gases are released.

Note 4: Breathing rate for workers is based on recommended value in NUREG-1536 (NRC 1997).

Note 5: Ground releases are conservatively assumed for Cat. 1 events; using a stack release will typically result in a lower dose at 100-m (Assumption 3.25).

Blue shading = calculated fields

Yellow shading = input fields

Input Parameters for Category 1 Dose Calculations:

Fuel Type:		
Average PWR / Average BWR / Maximum PWR / Maximum BWR	Average PWR	(Note 1)
Event Description:		
Basket Drop Onto Another Basket in Basket Staging Rack (Lifting Out)		
Event #:	1-05	
Location:	Cask Unloading Pool	
Event Frequency:	4.10E-02	
Number of Fuel Assemblies Damaged:	8	(Note 1)
Does the Event Occur in a Pool?	Yes / No	
HEPA Mitigation Factor:		
HEPA Filtration	0.01	Particulate Release (Note 3)
No HEPA Filtration	1.00	Gaseous Release (Note 3)
X/Q Value:		
Distance (m): 100 / 5,000 / 8,000 / 11,000	99.5% Acute / 50% Acute / 95% Overall Site / Max Sector Chronic	
	4.77E-04	(Note 2)
Breathing Rate (m^3/sec)	3.30E-04	(Note 4)
Ground Release?	Y	(Note 5)

Note 1: Average PWR fuel is used for all Category 1 event releases because it results in larger worker doses than Average BWR fuel.

Note 2: Chi/Q value for worker dose is based on chronic releases and 100-m distance to the receptor.

Note 3: HEPA filters, if available, are 99% effective in retaining particulates and volatiles (Cs) (Assumption 3.23). 100% of the Noble gases are released.

Note 4: Breathing rate for workers is based on recommended value in NUREG-1536 (NRC 1997).

Note 5: Ground releases are conservatively assumed for Cat. 1 events; using a stack release will typically result in a lower dose at 100-m (Assumption 3.25).

Blue shading = calculated fields

Yellow shading = input fields

Input Parameters for Category 1 Dose Calculations:

Fuel Type: (Average PWR / Average BWR / Maximum PWR / Maximum BWR)	Average PWR	(Note 1)
Event Description:	Basket Drop Onto Another Basket in Pool (Transfer Into Pool Storage)	
Event #:	1-06	
Location:	ATS Pool	
Event Frequency:	4.10E-02	
Number of Fuel Assemblies Damaged:	8	(Note 1)
Does the Event Occur in a Pool? (Yes / No)	Yes	
HEPA Mitigation Factor: (HEPA Filtration / No HEPA Filtration)	0.01	Particulate Release (Note 3)
	1.00	Gaseous Release (Note 3)
X/Q Value: Distance (m): (100 / 5,000 / 8,000 / 11,000); (99.5% Acute / 50% Acute / 95% Overall Site / Max Sector Chronic)	4.77E-04	(Note 2)
Breathing Rate (m^3/sec)	3.30E-04	(Note 4)
Ground Release?	Y	(Note 5)

Note 1: Average PWR fuel is used for all Category 1 event releases because it results in larger worker doses than Average BWR fuel.

Note 2: Chi/Q value for worker dose is based on chronic releases and 100-m distance to the receptor.

Note 3: HEPA filters, if available, are 99% effective in retaining particulates and volatiles (Cs) (Assumption 3.23). 100% of the Noble gases are released.

Note 4: Breathing rate for workers is based on recommended value in NUREG-1536 (NRC 1997).

Note 5: Ground releases are conservatively assumed for Cat. 1 events; using a stack release will typically result in a lower dose at 100-m (Assumption 3.25).

Blue shading = calculated fields

Yellow shading = input fields

Input Parameters for Category 1 Dose Calculations:

Fuel Type:	Average PWR (Note 1)	
Event Description:	Basket Drop Onto Another Basket in Pool (Transfer Out of Pool Storage)	
Event #:	1-07	
Location:	ATS Pool	
Event Frequency:	4.10E-02	
Number of Fuel Assemblies Damaged:	8	(Note 1)
Does the Event Occur in a Pool?	Yes	
HEPA Mitigation Factor:	0.01	Particulate Release (Note 3)
	1.00	Gaseous Release (Note 3)
X/Q Value:		
Distance (m): 100	99.5% Acute	
5,000	50% Acute	
8,000	95% Overall Site	
11,000	Max Sector Chronic	4.77E-04 (Note 2)
Breathing Rate (m^3/sec)	3.30E-04	(Note 4)
Ground Release?	Y	(Note 5)

Note 1: Average PWR fuel is used for all Category 1 event releases because it results in larger worker doses than Average BWR fuel.

Note 2: Chi/Q value for worker dose is based on chronic releases and 100-m distance to the receptor.

Note 3: HEPA filters, if available, are 99% effective in retaining particulates and volatiles (Cs) (Assumption 3.23). 100% of the Noble gases are released.

Note 4: Breathing rate for workers is based on recommended value in NUREG-1536 (NRC 1997).

Note 5: Ground releases are conservatively assumed for Cat. 1 events; using a stack release will typically result in a lower dose at 100-m (Assumption 3.25).

Blue shading = calculated fields

Yellow shading = input fields

Input Parameters for Category 1 Dose Calculations:

Fuel Type:

Average PWR
Average BWR
Maximum PWR
Maximum BWR

Average PWR (Note 1)

Event Description:

Basket Drop Onto Transfer Cart or Pool Floor

Event #:	1-08	
Location:	ATS Pool	
Event Frequency:	4.10E-02	
Number of Fuel Assemblies Damaged:	4	(Note 1)
Does the Event Occur in a Pool?	Yes / No	

HEPA Mitigation Factor:

HEPA Filtration
No HEPA Filtration

	0.01	Particulate Release (Note 3)
	1.00	Gaseous Release (Note 3)

X/Q Value:

Distance (m): 100, 5,000, 8,000, 11,000

99.5% Acute
50% Acute
95% Overall Site
Max Sector Chronic

4.77E-04 (Note 2)

Breathing Rate (m^3/sec)	3.30E-04	(Note 4)
Ground Release?	Y	(Note 5)

Note 1: Average PWR fuel is used for all Category 1 event releases because it results in larger worker doses than Average BWR fuel.

Note 2: Chi/Q value for worker dose is based on chronic releases and 100-m distance to the receptor.

Note 3: HEPA filters, if available, are 99% effective in retaining particulates and volatiles (Cs) (Assumption 3.23). 100% of the Noble gases are released.

Note 4: Breathing rate for workers is based on recommended value in NUREG-1536 (NRC 1997).

Note 5: Ground releases are conservatively assumed for Cat. 1 events; using a stack release will typically result in a lower dose at 100-m (Assumption 3.25).

Blue shading = calculated fields

Yellow shading = input fields

Input Parameters for Category 1 Dose Calculations:

Fuel Type:	Average PWR (Note 1)	
Event Description:	Basket Drop Back Into Pool	
Event #:	1-09	
Location:	ATS Pool	
Event Frequency:	4.10E-02	
Number of Fuel Assemblies Damaged:	4	(Note 1)
Does the Event Occur in a Pool?	Yes	
HEPA Mitigation Factor: HEPA Filtration	0.01	Particulate Release (Note 3)
HEPA Mitigation Factor: No HEPA Filtration	1.00	Gaseous Release (Note 3)
X/Q Value: Distance (m): 100; 99.5% Acute	4.77E-04	(Note 2)
Breathing Rate (m^3/sec)	3.30E-04	(Note 4)
Ground Release?	Y	(Note 5)

Note 1: Average PWR fuel is used for all Category 1 event releases because it results in larger worker doses than Average BWR fuel.

Note 2: Chi/Q value for worker dose is based on chronic releases and 100-m distance to the receptor.

Note 3: HEPA filters, if available, are 99% effective in retaining particulates and volatiles (Cs) (Assumption 3.23). 100% of the Noble gases are released.

Note 4: Breathing rate for workers is based on recommended value in NUREG-1536 (NRC 1997).

Note 5: Ground releases are conservatively assumed for Cat. 1 events; using a stack release will typically result in a lower dose at 100-m (Assumption 3.25).

Blue shading = calculated fields

Yellow shading = input fields

Input Parameters for Category 1 Dose Calculations:

Fuel Type:		
Average PWR / Average BWR / Maximum PWR / Maximum BWR	Average PWR	(Note 1)
Event Description:		
Basket Drop Onto ATS Hot Cell Floor		
Event #:	1-10	
Location:	ATS Hot Cell	
Event Frequency:	4.10E-02	
Number of Fuel Assemblies Damaged:	4	(Note 1)
Does the Event Occur in a Pool? (Yes / No)		
HEPA Mitigation Factor:		
HEPA Filtration	0.01	Particulate Release (Note 3)
No HEPA Filtration	1.00	Gaseous Release (Note 3)
X/Q Value:		
Distance (m): 100 / 5,000 / 8,000 / 11,000		
99.5% Acute / 50% Acute / 95% Overall Site / Max Sector Chronic	4.77E-04	(Note 2)
Breathing Rate (m^3/sec)	3.30E-04	(Note 4)
Ground Release?	Y	(Note 5)

Note 1: Average PWR fuel is used for all Category 1 event releases because it results in larger worker doses than Average BWR fuel.

Note 2: Chi/Q value for worker dose is based on chronic releases and 100-m distance to the receptor.

Note 3: HEPA filters, if available, are 99% effective in retaining particulates and volatiles (Cs) (Assumption 3.23). 100% of the Noble gases are released.

Note 4: Breathing rate for workers is based on recommended value in NUREG-1536 (NRC 1997).

Note 5: Ground releases are conservatively assumed for Cat. 1 events; using a stack release will typically result in a lower dose at 100-m (Assumption 3.25).

Blue shading = calculated fields

Yellow shading = input fields

Input Parameters for Category 1 Dose Calculations:

Fuel Type:	Average PWR (Note 1)	
Event Description:	Basket Drop Onto Another Basket in Dryer	
Event #:	1-11	
Location:	ATS Hot Cell	
Event Frequency:	4.10E-02	
Number of Fuel Assemblies Damaged:	8	(Note 1)
Does the Event Occur in a Pool?	No	
HEPA Mitigation Factor:	0.01	Particulate Release (Note 3)
	1.00	Gaseous Release (Note 3)
Distance (m): 100 / X/Q Value: 99.5% Acute	4.77E-04	(Note 2)
Breathing Rate (m^3/sec)	3.30E-04	(Note 4)
Ground Release?	Y	(Note 5)

Note 1: Average PWR fuel is used for all Category 1 event releases because it results in larger worker doses than Average BWR fuel.

Note 2: Chi/Q value for worker dose is based on chronic releases and 100-m distance to the receptor.

Note 3: HEPA filters, if available, are 99% effective in retaining particulates and volatiles (Cs) (Assumption 3.23). 100% of the Noble gases are released.

Note 4: Breathing rate for workers is based on recommended value in NUREG-1536 (NRC 1997).

Note 5: Ground releases are conservatively assumed for Cat. 1 events; using a stack release will typically result in a lower dose at 100-m (Assumption 3.25).

Blue shading = calculated fields

Yellow shading = input fields

Input Parameters for Category 1 Dose Calculations:

Fuel Type:		
Average PWR / Average BWR / Maximum PWR / Maximum BWR	Average PWR	(Note 1)
Event Description:		
SFA Drop Onto Another SFA in Dryer		
Event #:	1-12	
Location:	ATS Hot Cell	
Event Frequency:	2.34E-01	
Number of Fuel Assemblies Damaged:	2	(Note 1)
Does the Event Occur in a Pool?	Yes / No	
HEPA Mitigation Factor:		
HEPA Filtration	0.01	Particulate Release (Note 3)
No HEPA Filtration	1.00	Gaseous Release (Note 3)
X/Q Value:		
Distance (m): 100 / 5,000 / 8,000 / 11,000; 99.5% Acute / 50% Acute / 95% Overall Site / Max Sector Chronic	4.77E-04	(Note 2)
Breathing Rate (m^3/sec)	3.30E-04	(Note 4)
Ground Release?	Y	(Note 5)

Note 1: Average PWR fuel is used for all Category 1 event releases because it results in larger worker doses than Average BWR fuel.

Note 2: Chi/Q value for worker dose is based on chronic releases and 100-m distance to the receptor.

Note 3: HEPA filters, if available, are 99% effective in retaining particulates and volatiles (Cs) (Assumption 3.23). 100% of the Noble gases are released.

Note 4: Breathing rate for workers is based on recommended value in NUREG-1536 (NRC 1997).

Note 5: Ground releases are conservatively assumed for Cat. 1 events; using a stack release will typically result in a lower dose at 100-m (Assumption 3.25).

Blue shading = calculated fields

Yellow shading = input fields

Input Parameters for Category 1 Dose Calculations:

Fuel Type:	Average PWR (Note 1)	
Event Description:	SFA Drop Onto ATS Hot Cell Floor	
Event #:	1-13	
Location:	ATS Hot Cell	
Event Frequency:	2.34E-01	
Number of Fuel Assemblies Damaged:	1	(Note 1)
Does the Event Occur in a Pool?	Yes / No	
HEPA Mitigation Factor:	0.01	Particulate Release (Note 3)
	1.00	Gaseous Release (Note 3)
X/Q Value:		
Distance (m): 100 / 5,000 / 8,000 / 11,000	99.5% Acute / 50% Acute / 95% Overall Site / Max Sector Chronic	4.77E-04 (Note 2)
Breathing Rate (m^3/sec)	3.30E-04	(Note 4)
Ground Release?	Y	(Note 5)

Note 1: Average PWR fuel is used for all Category 1 event releases because it results in larger worker doses than Average BWR fuel.

Note 2: Chi/Q value for worker dose is based on chronic releases and 100-m distance to the receptor.

Note 3: HEPA filters, if available, are 99% effective in retaining particulates and volatiles (Cs) (Assumption 3.23). 100% of the Noble gases are released.

Note 4: Breathing rate for workers is based on recommended value in NUREG-1536 (NRC 1997).

Note 5: Ground releases are conservatively assumed for Cat. 1 events; using a stack release will typically result in a lower dose at 100-m (Assumption 3.25).

Blue shading = calculated fields

Yellow shading = input fields

Input Parameters for Category 1 Dose Calculations:

Fuel Type:		
Average PWR / Average BWR / Maximum PWR / Maximum BWR	Average PWR	(Note 1)
Event Description:		
SFA Drop Onto Another SFA in DC		
Event #:	1-14	
Location:	ATS Hot Cell	
Event Frequency:	2.34E-01	
Number of Fuel Assemblies Damaged:	2	(Note 1)
Does the Event Occur in a Pool?	Yes / No	
HEPA Mitigation Factor:		
HEPA Filtration	0.01	Particulate Release (Note 3)
No HEPA Filtration	1.00	Gaseous Release (Note 3)
X/Q Value:		
Distance (m): 100 / 5,000 / 8,000 / 11,000		
99.5% Acute / 50% Acute / 95% Overall Site / Max Sector Chronic	4.77E-04	(Note 2)
Breathing Rate (m^3/sec)	3.30E-04	(Note 4)
Ground Release?	Y	(Note 5)

Note 1: Average PWR fuel is used for all Category 1 event releases because it results in larger worker doses than Average BWR fuel.

Note 2: Chi/Q value for worker dose is based on chronic releases and 100-m distance to the receptor.

Note 3: HEPA filters, if available, are 99% effective in retaining particulates and volatiles (Cs) (Assumption 3.23). 100% of the Noble gases are released.

Note 4: Breathing rate for workers is based on recommended value in NUREG-1536 (NRC 1997).

Note 5: Ground releases are conservatively assumed for Cat. 1 events; using a stack release will typically result in a lower dose at 100-m (Assumption 3.25).

Blue shading = calculated fields

Yellow shading = input fields

Summary of Inhalation and Submersion Dose Calculations

Event: **1-01** SFA Drop Onto Another SFA in Cask

Fuel Type: Average PWR

Organ	Inhalation Dose (rem)	Dose Term for Regulation	Submersion Dose (rem)	Dose Term for Regulation	Sum of Inhalation and Submersion (rem)	Dose Term for Regulation
Gonad	6.90E-04		1.40E-04		8.30E-04	
Breast	6.91E-04		1.00E+00		1.00E+00	
Lung	6.92E-04		1.37E-04		8.28E-04	
R Marrow	6.90E-04		1.30E-04		8.21E-04	
B Surface	6.90E-04		2.63E-04		9.53E-04	
Thyroid	1.27E-02	<CDE	1.41E-04		1.28E-02	
Remainder	6.90E-04		1.30E-04		8.21E-04	
Whole Body	**1.05E-03**	<CEDE	**1.42E-04**	<DDE	**1.19E-03**	<TEDE=CEDE+DDE
Eye Lens	N/A		0.00E+00	<EYE		
Skin	N/A		1.58E-02	<SKIN		
					1.28E-02	<MAX CDE + DDE

Note: Bolded results are added together to calculate TEDE (CEDE + DDE)

RESULTS:

Dose Term	100-m Non-Involved Worker Dose (rem/event)	Frequency (events/year)	Annual Dose (rem/year)
TEDE:	1.19E-03	2.34E-01	2.79E-04
Max. CDE + DDE:	1.28E-02	2.34E-01	3.00E-03
Eye:	0.00E+00	2.34E-01	0.00E+00
Skin:	1.58E-02	2.34E-01	3.70E-03

Dose Terms:
TEDE = total effective dose equivalent
CEDE = inhalation whole body
DDE = submersion whole body
CDE = maximum internal organ, inhalation

Summary of Inhalation and Submersion Dose Calculations

Event: **1-02** SFA Collision

Fuel Type: Average PWR

Organ	Inhalation Dose (rem)	Dose Term for Regulation	Submersion Dose (rem)	Dose Term for Regulation	Sum of Inhalation and Submersion (rem)	Dose Term for Regulation
Gonad	3.45E-04		7.00E-05		4.15E-04	
Breast	3.45E-04		1.00E+00		1.00E+00	
Lung	3.46E-04		6.84E-05		4.14E-04	
R Marrow	3.45E-04		6.52E-05		4.10E-04	
B Surface	3.45E-04		1.32E-04		4.77E-04	
Thyroid	6.34E-03	<CDE	7.06E-05		6.41E-03	
Remainder	3.45E-04		6.52E-05		4.10E-04	
Whole Body	**5.25E-04**	<CEDE	**7.12E-05**	<DDE	**5.96E-04**	<TEDE=CEDE+DDE
Eye Lens	N/A		0.00E+00	<EYE		
Skin	N/A		7.90E-03	<SKIN		
					6.41E-03	<MAX CDE + DDE

Note: Bolded results are added together to calculate TEDE (CEDE + DDE)

RESULTS:

Dose Term	100-m Non-Involved Worker Dose (rem/event)	Frequency (events/year)	Annual Dose (rem/year)
TEDE:	5.96E-04	3.90E-02	2.33E-05
Max. CDE + DDE:	6.41E-03	3.90E-02	2.50E-04
Eye:	0.00E+00	3.90E-02	0.00E+00
Skin:	7.90E-03	3.90E-02	3.08E-04

Dose Terms:
TEDE = total effective dose equivalent
CEDE = inhalation whole body
DDE = submersion whole body
CDE = maximum internal organ, inhalation

Summary of Inhalation and Submersion Dose Calculations

Event: **1-03** SFA Drop Onto Empty Basket

Fuel Type: Average PWR

Organ	Inhalation Dose (rem)	Dose Term for Regulation	Submersion Dose (rem)	Dose Term for Regulation	Sum of Inhalation and Submersion (rem)	Dose Term for Regulation
Gonad	3.45E-04		7.00E-05		4.15E-04	
Breast	3.45E-04		1.00E+00		1.00E+00	
Lung	3.46E-04		6.84E-05		4.14E-04	
R Marrow	3.45E-04		6.52E-05		4.10E-04	
B Surface	3.45E-04		1.32E-04		4.77E-04	
Thyroid	6.34E-03	<CDE	7.06E-05		6.41E-03	
Remainder	3.45E-04		6.52E-05		4.10E-04	
Whole Body	**5.25E-04**	<CEDE	**7.12E-05**	<DDE	**5.96E-04**	<TEDE=CEDE+DDE
Eye Lens	N/A		0.00E+00	<EYE		
Skin	N/A		7.90E-03	<SKIN		
					6.41E-03	<MAX CDE + DDE

Note: Bolded results are added together to calculate TEDE (CEDE + DDE)

RESULTS:

Dose Term	100-m Non-Involved Worker Dose (rem/event)	Frequency (events/year)	Annual Dose (rem/year)
TEDE:	5.96E-04	4.22E-02	2.51E-05
Max. CDE + DDE:	6.41E-03	4.22E-02	2.70E-04
Eye:	0.00E+00	4.22E-02	0.00E+00
Skin:	7.90E-03	4.22E-02	3.33E-04

Dose Terms:
TEDE = total effective dose equivalent
CEDE = inhalation whole body
DDE = submersion whole body
CDE = maximum internal organ, inhalation

Summary of Inhalation and Submersion Dose Calculations

Event: **1-04** SFA Drop Onto Another SFA in Basket Staging Rack (Lowering Into)

Fuel Type: Average PWR

Organ	Inhalation Dose (rem)	Dose Term for Regulation	Submersion Dose (rem)	Dose Term for Regulation	Sum of Inhalation and Submersion (rem)	Dose Term for Regulation
Gonad	6.90E-04		1.40E-04		8.30E-04	
Breast	6.91E-04		1.00E+00		1.00E+00	
Lung	6.92E-04		1.37E-04		8.28E-04	
R Marrow	6.90E-04		1.30E-04		8.21E-04	
B Surface	6.90E-04		2.63E-04		9.53E-04	
Thyroid	1.27E-02	<CDE	1.41E-04		1.28E-02	
Remainder	6.90E-04		1.30E-04		8.21E-04	
Whole Body	**1.05E-03**	<CEDE	**1.42E-04**	<DDE	**1.19E-03**	<TEDE=CEDE+DDE
Eye Lens	N/A		0.00E+00	<EYE		
Skin	N/A		1.58E-02	<SKIN		
					1.28E-02	<MAX CDE + DDE

Note: Bolded results are added together to calculate TEDE (CEDE + DDE)

RESULTS:

Dose Term	100-m Non-Involved Worker Dose (rem/event)	Frequency (events/year)	Annual Dose (rem/year)
TEDE:	1.19E-03	1.92E-01	2.29E-04
Max. CDE + DDE:	1.28E-02	1.92E-01	2.46E-03
Eye:	0.00E+00	1.92E-01	0.00E+00
Skin:	1.58E-02	1.92E-01	3.03E-03

Dose Terms:
TEDE = total effective dose equivalent
CEDE = inhalation whole body
DDE = submersion whole body
CDE = maximum internal organ, inhalation

Summary of Inhalation and Submersion Dose Calculations

Event: **1-05** Basket Drop Onto Another Basket in Basket Staging Rack (Lifting Out)

Fuel Type: Average PWR

Organ	Inhalation Dose (rem)	Dose Term for Regulation	Submersion Dose (rem)	Dose Term for Regulation	Sum of Inhalation and Submersion (rem)	Dose Term for Regulation
Gonad	2.76E-03		5.60E-04		3.32E-03	
Breast	2.76E-03		1.00E+00		1.00E+00	
Lung	2.77E-03		5.47E-04		3.31E-03	
R Marrow	2.76E-03		5.22E-04		3.28E-03	
B Surface	2.76E-03		1.05E-03		3.81E-03	
Thyroid	5.07E-02	<CDE	5.65E-04		5.13E-02	
Remainder	2.76E-03		5.22E-04		3.28E-03	
Whole Body	**4.20E-03**	<CEDE	**5.70E-04**	<DDE	**4.77E-03**	<TEDE=CEDE+DDE
Eye Lens	N/A		0.00E+00	<EYE		
Skin	N/A		6.32E-02	<SKIN		
					5.13E-02	<MAX CDE + DDE

Note: Bolded results are added together to calculate TEDE (CEDE + DDE)

RESULTS:

Dose Term	100-m Non-Involved Worker Dose (rem/event)	Frequency (events/year)	Annual Dose (rem/year)
TEDE:	4.77E-03	4.10E-02	1.96E-04
Max. CDE + DDE:	5.13E-02	4.10E-02	2.10E-03
Eye:	0.00E+00	4.10E-02	0.00E+00
Skin:	6.32E-02	4.10E-02	2.59E-03

Dose Terms:
TEDE = total effective dose equivalent
CEDE = inhalation whole body
DDE = submersion whole body
CDE = maximum internal organ, inhalation

Summary of Inhalation and Submersion Dose Calculations

Event: **1-06** Basket Drop Onto Another Basket in Pool (Transfer Into Pool Storage)

Fuel Type: Average PWR

Organ	Inhalation Dose (rem)	Dose Term for Regulation	Submersion Dose (rem)	Dose Term for Regulation	Sum of Inhalation and Submersion (rem)	Dose Term for Regulation
Gonad	2.76E-03		5.60E-04		3.32E-03	
Breast	2.76E-03		1.00E+00		1.00E+00	
Lung	2.77E-03		5.47E-04		3.31E-03	
R Marrow	2.76E-03		5.22E-04		3.28E-03	
B Surface	2.76E-03		1.05E-03		3.81E-03	
Thyroid	5.07E-02	<CDE	5.65E-04		5.13E-02	
Remainder	2.76E-03		5.22E-04		3.28E-03	
Whole Body	**4.20E-03**	<CEDE	**5.70E-04**	<DDE	**4.77E-03**	<TEDE=CEDE+DDE
Eye Lens	N/A		0.00E+00	<EYE		
Skin	N/A		6.32E-02	<SKIN		
					5.13E-02	<MAX CDE + DDE

Note: Bolded results are added together to calculate TEDE (CEDE + DDE)

RESULTS:

Dose Term	100-m Non-Involved Worker Dose (rem/event)	Frequency (events/year)	Annual Dose (rem/year)
TEDE:	4.77E-03	4.10E-02	1.96E-04
Max. CDE + DDE:	5.13E-02	4.10E-02	2.10E-03
Eye:	0.00E+00	4.10E-02	0.00E+00
Skin:	6.32E-02	4.10E-02	2.59E-03

Dose Terms:
TEDE = total effective dose equivalent
CEDE = inhalation whole body
DDE = submersion whole body
CDE = maximum internal organ, inhalation

Summary of Inhalation and Submersion Dose Calculations

Event: **1-07** Basket Drop Onto Another Basket in Pool (Transfer Out of Pool Storage)

Fuel Type: Average PWR

Organ	Inhalation Dose (rem)	Dose Term for Regulation	Submersion Dose (rem)	Dose Term for Regulation	Sum of Inhalation and Submersion (rem)	Dose Term for Regulation
Gonad	2.76E-03		5.60E-04		3.32E-03	
Breast	2.76E-03		1.00E+00		1.00E+00	
Lung	2.77E-03		5.47E-04		3.31E-03	
R Marrow	2.76E-03		5.22E-04		3.28E-03	
B Surface	2.76E-03		1.05E-03		3.81E-03	
Thyroid	5.07E-02	<CDE	5.65E-04		5.13E-02	
Remainder	2.76E-03		5.22E-04		3.28E-03	
Whole Body	**4.20E-03**	<CEDE	**5.70E-04**	<DDE	**4.77E-03**	<TEDE=CEDE+DDE
Eye Lens	N/A		0.00E+00	<EYE		
Skin	N/A		6.32E-02	<SKIN		
					5.13E-02	<MAX CDE + DDE

Note: Bolded results are added together to calculate TEDE (CEDE + DDE)

RESULTS:

Dose Term	100-m Non-Involved Worker Dose (rem/event)	Frequency (events/year)	Annual Dose (rem/year)
TEDE:	4.77E-03	4.10E-02	1.96E-04
Max. CDE + DDE:	5.13E-02	4.10E-02	2.10E-03
Eye:	0.00E+00	4.10E-02	0.00E+00
Skin:	6.32E-02	4.10E-02	2.59E-03

Dose Terms:
TEDE = total effective dose equivalent
CEDE = inhalation whole body
DDE = submersion whole body
CDE = maximum internal organ, inhalation

Summary of Inhalation and Submersion Dose Calculations

Event: **1-08** Basket Drop Onto Transfer Cart or Pool Floor

Fuel Type: Average PWR

Organ	Inhalation Dose (rem)	Dose Term for Regulation	Submersion Dose (rem)	Dose Term for Regulation	Sum of Inhalation and Submersion (rem)	Dose Term for Regulation
Gonad	1.38E-03		2.80E-04		1.66E-03	
Breast	1.38E-03		1.00E+00		1.00E+00	
Lung	1.38E-03		2.73E-04		1.66E-03	
R Marrow	1.38E-03		2.61E-04		1.64E-03	
B Surface	1.38E-03		5.27E-04		1.91E-03	
Thyroid	2.54E-02	<CDE	2.82E-04		2.56E-02	
Remainder	1.38E-03		2.61E-04		1.64E-03	
Whole Body	**2.10E-03**	<CEDE	**2.85E-04**	<DDE	**2.39E-03**	<TEDE=CEDE+DDE
Eye Lens	N/A		0.00E+00	<EYE		
Skin	N/A		3.16E-02	<SKIN		
					2.56E-02	<MAX CDE + DDE

Note: Bolded results are added together to calculate TEDE (CEDE + DDE)

RESULTS:

Dose Term	100-m Non-Involved Worker Dose (rem/event)	Frequency (events/year)	Annual Dose (rem/year)
TEDE:	2.39E-03	4.10E-02	9.78E-05
Max. CDE + DDE:	2.56E-02	4.10E-02	1.05E-03
Eye:	0.00E+00	4.10E-02	0.00E+00
Skin:	3.16E-02	4.10E-02	1.30E-03

Dose Terms:
TEDE = total effective dose equivalent
CEDE = inhalation whole body
DDE = submersion whole body
CDE = maximum internal organ, inhalation

Summary of Inhalation and Submersion Dose Calculations

Event: **1-09** Basket Drop Back Into Pool

Fuel Type: Average PWR

Organ	Inhalation Dose (rem)	Dose Term for Regulation	Submersion Dose (rem)	Dose Term for Regulation	Sum of Inhalation and Submersion (rem)	Dose Term for Regulation
Gonad	1.38E-03		2.80E-04		1.66E-03	
Breast	1.38E-03		1.00E+00		1.00E+00	
Lung	1.38E-03		2.73E-04		1.66E-03	
R Marrow	1.38E-03		2.61E-04		1.64E-03	
B Surface	1.38E-03		5.27E-04		1.91E-03	
Thyroid	2.54E-02	<CDE	2.82E-04		2.56E-02	
Remainder	1.38E-03		2.61E-04		1.64E-03	
Whole Body	**2.10E-03**	<CEDE	**2.85E-04**	<DDE	**2.39E-03**	<TEDE=CEDE+DDE
Eye Lens	N/A		0.00E+00	<EYE		
Skin	N/A		3.16E-02	<SKIN		
					2.56E-02	<MAX CDE + DDE

Note: Bolded results are added together to calculate TEDE (CEDE + DDE)

RESULTS:

Dose Term	100-m Non-Involved Worker Dose (rem/event)	Frequency (events/year)	Annual Dose (rem/year)
TEDE:	2.39E-03	4.10E-02	9.78E-05
Max. CDE + DDE:	2.56E-02	4.10E-02	1.05E-03
Eye:	0.00E+00	4.10E-02	0.00E+00
Skin:	3.16E-02	4.10E-02	1.30E-03

Dose Terms:
TEDE = total effective dose equivalent
CEDE = inhalation whole body
DDE = submersion whole body
CDE = maximum internal organ, inhalation

Summary of Inhalation and Submersion Dose Calculations

Event: **1-10** Basket Drop Onto ATS Hot Cell Floor

Fuel Type: Average PWR

Organ	Inhalation Dose (rem)	Dose Term for Regulation	Submersion Dose (rem)	Dose Term for Regulation	Sum of Inhalation and Submersion (rem)	Dose Term for Regulation
Gonad	1.70E-01		2.80E-04		1.70E-01	
Breast	1.52E-01		1.00E+00		1.15E+00	
Lung	1.77E-01		2.73E-04		1.77E-01	
R Marrow	1.63E-01		2.61E-04		1.63E-01	
B Surface	1.83E-01	<MAX CDE	5.27E-04		1.84E-01	
Thyroid	1.77E-01		2.82E-04		1.78E-01	
Remainder	1.78E-01		2.61E-04		1.78E-01	
Whole Body	**6.30E-03**	<CEDE	**2.85E-04**	<DDE	**6.59E-03**	<TEDE=CEDE+DDE
Eye Lens	N/A		0.00E+00	<EYE		
Skin	N/A		3.16E-02	<SKIN		
					1.84E-01	<MAX CDE + DDE

Note: Bolded results are added together to calculate TEDE (CEDE + DDE)

RESULTS:

Dose Term	100-m Non-Involved Worker Dose (rem/event)	Frequency (events/year)	Annual Dose (rem/year)
TEDE:	6.59E-03	4.10E-02	2.70E-04
Max. CDE + DDE:	1.84E-01	4.10E-02	7.53E-03
Eye:	0.00E+00	4.10E-02	0.00E+00
Skin:	3.16E-02	4.10E-02	1.30E-03

Dose Terms:
TEDE = total effective dose equivalent
CEDE = inhalation whole body
DDE = submersion whole body
CDE = maximum internal organ, inhalation

Summary of Inhalation and Submersion Dose Calculations

Event: **1-11** Basket Drop Onto Another Basket in Dryer

Fuel Type: Average PWR

Organ	Inhalation Dose (rem)	Dose Term for Regulation	Submersion Dose (rem)	Dose Term for Regulation	Sum of Inhalation and Submersion (rem)	Dose Term for Regulation
Gonad	3.40E-01		5.60E-04		3.40E-01	
Breast	3.04E-01		1.00E+00		1.30E+00	
Lung	3.54E-01		5.47E-04		3.54E-01	
R Marrow	3.26E-01		5.22E-04		3.27E-01	
B Surface	3.67E-01	<MAX CDE	1.05E-03		3.68E-01	
Thyroid	3.55E-01		5.65E-04		3.56E-01	
Remainder	3.55E-01		5.22E-04		3.56E-01	
Whole Body	**1.26E-02**	<CEDE	**5.70E-04**	<DDE	**1.32E-02**	<TEDE=CEDE+DDE
Eye Lens	N/A		0.00E+00	<EYE		
Skin	N/A		6.32E-02	<SKIN		
					3.67E-01	<MAX CDE + DDE

Note: Bolded results are added together to calculate TEDE (CEDE + DDE)

RESULTS:

Dose Term	100-m Non-Involved Worker Dose (rem/event)	Frequency (events/year)	Annual Dose (rem/year)
TEDE:	1.32E-02	4.10E-02	5.40E-04
Max. CDE + DDE:	3.67E-01	4.10E-02	1.51E-02
Eye:	0.00E+00	4.10E-02	0.00E+00
Skin:	6.32E-02	4.10E-02	2.59E-03

Dose Terms:
TEDE = total effective dose equivalent
CEDE = inhalation whole body
DDE = submersion whole body
CDE = maximum internal organ, inhalation

Summary of Inhalation and Submersion Dose Calculations

Event: **1-12** SFA Drop Onto Another SFA in Dryer

Fuel Type: Average PWR

Organ	Inhalation Dose (rem)	Dose Term for Regulation	Submersion Dose (rem)	Dose Term for Regulation	Sum of Inhalation and Submersion (rem)	Dose Term for Regulation
Gonad	8.49E-02		1.40E-04		8.50E-02	
Breast	7.59E-02		1.00E+00		1.08E+00	
Lung	8.85E-02		1.37E-04		8.86E-02	
R Marrow	8.15E-02		1.30E-04		8.16E-02	
B Surface	9.17E-02	<MAX CDE	2.63E-04		9.19E-02	
Thyroid	8.87E-02		1.41E-04		8.89E-02	
Remainder	8.88E-02		1.30E-04		8.89E-02	
Whole Body	**3.15E-03**	<CEDE	**1.42E-04**	<DDE	**3.29E-03**	<TEDE=CEDE+DDE
Eye Lens	N/A		0.00E+00	<EYE		
Skin	N/A		1.58E-02	<SKIN		
					9.18E-02	<MAX CDE + DDE

Note: Bolded results are added together to calculate TEDE (CEDE + DDE)

RESULTS:

Dose Term	100-m Non-Involved Worker Dose (rem/event)	Frequency (events/year)	Annual Dose (rem/year)
TEDE:	3.29E-03	2.34E-01	7.72E-04
Max. CDE + DDE:	9.18E-02	2.34E-01	2.15E-02
Eye:	0.00E+00	2.34E-01	0.00E+00
Skin:	1.58E-02	2.34E-01	3.70E-03

Dose Terms:
TEDE = total effective dose equivalent
CEDE = inhalation whole body
DDE = submersion whole body
CDE = maximum internal organ, inhalation

Summary of Inhalation and Submersion Dose Calculations

Event: **1-13** SFA Drop Onto ATS Hot Cell Floor

Fuel Type: Average PWR

Organ	Inhalation Dose (rem)	Dose Term for Regulation	Submersion Dose (rem)	Dose Term for Regulation	Sum of Inhalation and Submersion (rem)	Dose Term for Regulation
Gonad	4.25E-02		7.00E-05		4.25E-02	
Breast	3.80E-02		1.00E+00		1.04E+00	
Lung	4.49E-02		6.84E-05		4.50E-02	
R Marrow	4.08E-02		6.52E-05		4.09E-02	
B Surface	4.59E-02	<MAX CDE	1.32E-04		4.60E-02	
Thyroid	4.44E-02		7.06E-05		4.45E-02	
Remainder	4.45E-02		6.52E-05		4.45E-02	
Whole Body	**1.70E-03**	<CEDE	**7.12E-05**	<DDE	**1.77E-03**	<TEDE=CEDE+DDE
Eye Lens	N/A		0.00E+00	<EYE		
Skin	N/A		7.90E-03	<SKIN		
					4.59E-02	<MAX CDE + DDE

Note: Bolded results are added together to calculate TEDE (CEDE + DDE)

RESULTS:

Dose Term	100-m Non-Involved Worker Dose (rem/event)	Frequency (events/year)	Annual Dose (rem/year)
TEDE:	1.77E-03	2.34E-01	4.14E-04
Max. CDE + DDE:	4.59E-02	2.34E-01	1.08E-02
Eye:	0.00E+00	2.34E-01	0.00E+00
Skin:	7.90E-03	2.34E-01	1.85E-03

Dose Terms:
TEDE = total effective dose equivalent
CEDE = inhalation whole body
DDE = submersion whole body
CDE = maximum internal organ, inhalation

Summary of Inhalation and Submersion Dose Calculations

Event: **1-14** SFA Drop Onto Another SFA in DC

Fuel Type: Average PWR

Organ	Inhalation Dose (rem)	Dose Term for Regulation	Submersion Dose (rem)	Dose Term for Regulation	Sum of Inhalation and Submersion (rem)	Dose Term for Regulation
Gonad	8.49E-02		1.40E-04		8.50E-02	
Breast	7.59E-02		1.00E+00		1.08E+00	
Lung	8.85E-02		1.37E-04		8.86E-02	
R Marrow	8.15E-02		1.30E-04		8.16E-02	
B Surface	9.17E-02	<MAX CDE	2.63E-04		9.19E-02	
Thyroid	8.87E-02		1.41E-04		8.89E-02	
Remainder	8.88E-02		1.30E-04		8.89E-02	
Whole Body	**3.15E-03**	<CEDE	**1.42E-04**	<DDE	**3.29E-03**	<TEDE=CEDE+DDE
Eye Lens	N/A		0.00E+00	<EYE		
Skin	N/A		1.58E-02	<SKIN		
					9.18E-02	<MAX CDE + DDE

Note: Bolded results are added together to calculate TEDE (CEDE + DDE)

RESULTS:

Dose Term	100-m Non-Involved Worker Dose (rem/event)	Frequency (events/year)	Annual Dose (rem/year)
TEDE:	3.29E-03	2.34E-01	7.72E-04
Max. CDE + DDE:	9.18E-02	2.34E-01	2.15E-02
Eye:	0.00E+00	2.34E-01	0.00E+00
Skin:	1.58E-02	2.34E-01	3.70E-03

Dose Terms:
TEDE = total effective dose equivalent
CEDE = inhalation whole body
DDE = submersion whole body
CDE = maximum internal organ, inhalation

Validation Test Cases for Formulas Contained in this Workbook

Worksheet	Cell Range	Test Cell	Formula	Input	Output	Hand-Calculated Results*
Avg Dose	C68 to L68 & P68 to Y68	C68	=SUM(C66:C67)	C66=0, C67=0.489	C68=0.489	C68=0.489
Max Dose	C68 to L68 & P68 to Y68	C68	=SUM(C66:C67)	C66=1, C67=1	C68=2	C68=2.0
Crud	D7	D7	=IF(D3="y",5902*EXP(-LN(2)*D5/2.73),0)	D3=y, D5=25	D7=10.3	D7=10.34
Crud	D8	D8	=IF(D3="y",7415*EXP(-LN(2)*D5/2.73),0)	D3=y, D5=25	D8=13.0	D8=12.99
Crud	D9	D9	=140*EXP(-LN(2)*D5/5.271)*IF(Input!E18=1,1,0.5)	D5=25, Input!E18=2	D9=2.6	D9=2.61
Crud	D10	D10	=1254*EXP(-LN(2)*D5/5.271)*IF(Input!E18=1,1,0.5)	D5=25, Input!E18=2	D10=23.4	D10=23.42
Crud	B20	B20	=(D7*D12)/1000000	D7=10.3, D12=449,003	B20=4.6	B20=4.62
Crud	B21	B21	=(D8*D13)/1000000	D8=13.0, D13=168,148	B21=2.2	B21=2.19
Crud	B22	B22	=(D9*D12)/1000000	D9=2.6, D12=449,003	B22=1.2	B22=1.17
Crud	B23	B23	=(D10*D13)/1000000	D10=23.4, D13=168,148	B23=3.9	B23=3.93
Crud	B33 to I36	B33	=$D$9*$D$12*B$28*$B$16*$B$17	D9=2.6, D12=449,003, B28=4.76E-9, B16=3.7E4, B17=100	B33=2.07E4	B33=2.056E4
Grouped Sources	C6 to J10	C6	=SUM(Groupings!C$7:C$9)	Groupings!(C7=7.3E3, C8=7.07, C9=0)	C6=7.30E3	C6=7307.1
RFs	H5:H12, H19:26	H5	=C5*D5*E5*F5*G5	C5=1, D5=0.3, E5=1, F5=1, G5=1	H5=0.30	H5=0.30
Submersion	B9 to B18	B9	=IF(Input!$G$5=1,'Avg Dose'!C$68,IF(Input!$G$5=2,'Avg Dose'!P$68,IF(Input!$G$5=3,'Max Dose'!C$68,IF(Input!$G$5=4,'Max Dose'!P$68,"Error"))))	Input!G5=1, Avg Dose!C68=4.89E-1, Avg Dose!P68=1.65E-1, Max Dose!C68=2.44, Max Dose!P68=8.79E-1	B9=4.89E-1	B9=4.89E-1
Submersion	G9 to G18	G9	=B9*C9*D9*E9*F9	B9=0.489, C9=2, D9=0.3, E9=1, F9=4.77E-4	G9=1.40E-4	G9=1.40E-4
Gonad	E8 to E12	E8	=IF(Input!$G$21=1,RFs!$H$26,RFs!$H$12)	Input!G21=2, RFs!H26=0, RFs!H12=1.50E-7	E8=1.50E-7	E8=1.50E-7
Gonad	I8 to I12	I8	=IF($C$8="N/A", 0, $C$8*$D$8*$E$8*$F$8*$G$8*$H$8)	C8=4.58E11, D8=2, E8=1.50E-7, F8=1.0E-2, G8=3.30E-4, F8=4.77E-4	I8=2.16E-4	I8=2.163E-4
Breast, Lung, Marrow, Bone Sur, Thyroid, Remainder & Whole Body	E8 to E12	(same as formulas for Gonad)				

Validation Test Cases for Formulas Contained in this Workbook

Worksheet	Cell Range	Test Cell	Formula	Input	Output	Hand-Calculated Results*
Breast, Lung, Marrow, Bone Sur, Thyroid, Remainder & Whole Body	I8 to I12	(same as formulas for Gonad)				
Annual Dose	L62 to O62	L62	=SUM(L46:L61)	(see Annual Dose tab)	L62=1.15E-2	L62=1.153E-2
Summary	G14	G14	=C14+E14	C14=3.15E-3, E14=1.42E-4	G14=3.29E-3	G14=3.292E-3
Summary	G18	G18	=MAX(C7:C13)+E14	MAX=C11=9.17E-2, E14=1.42E-4	G18=9.18E-2	G18=9.184E-2
Summary	E25 to E28	E25	=C25*D25	C25=3.29E-3, D25=2.34E-1	E25=7.72E-4	E25=7.699E-4

* Output values may differ slightly from hand calculations due to rounding errors. These differences are acceptable for the range of input values used in this calculation.

Attachment VI

Probability of Yoke Drop Onto SNF

I. Summary

One of the event sequences evaluated to support the MGR preclosure safety analysis for Site Recommendation is the drop of a heavy object in the Waste Handling Building that could impact spent nuclear fuel (SNF) and cause a radiological release. Upon review of preliminary design information (CRWMS M&O 2000d), the lifting yoke from an overhead crane was estimated to be the heaviest piece of equipment that could potentially fall on SNF and cause a release. The purpose of this evaluation was to quantify, by fault tree analysis, the probability of a yoke drop onto a vulnerable wasteform (i.e., SNF not contained in a sealed cask, canister or WP) in the Waste Handling Building.

II. Assumptions

The fault tree evaluation relied on the following assumptions regarding the design and operation of the overhead cranes and control systems:

- Redundancy for active components (e.g., cable, hoisting drum, brake selenoid) of the crane system required to support the load (Assumption 3.28).
- Redundant control systems to prevent a spurious movement or detect an operator error that could result in a physical impact to vulnerable SNF (Assumption 3.28).
- The beta factor for common-mode failures is 0.1 (Assumption 3.29).
- Maintenance on the control systems is performed once per year (Assumption 3.11).
- The exposure time that a lifting yoke is suspended above SNF is 1 minute per lift (Assumption 3.30).

III. Fault Tree

A fault tree was constructed to quantify the top event probability of a yoke drop (per lift) onto SNF. The top event was postulated to occur from either a human-induced event sequence or an electrical or mechanical failure. Since the MGR design is in a conceptual stage, the crane system was assumed to consist of redundant cables, hoisting drums, brake systems, and control systems.

An electrical or mechanical failure is postulated to occur if two of the redundant electrical/mechanical components fail to perform on demand, or are rendered inoperable by a common-mode failure initiator such as loss-of-power or earthquake.

The human-induced event sequence that was postulated to result in a yoke drop assumes an operator error that creates a condition for a yoke drop to occur and failure of the control/interlock system that would normally detect and prevent such a drop. Common-mode failures were also used to model the failure of the redundant control systems. A control system failure is postulated to occur due to an error of commission (EOC), e.g., not following procedures, during maintenance of the crane control system and failure to recover from the error of commission.

The fault tree illustrated in Figure 1 quantifies the expected probability (per lift) of a yoke drop onto an exposed wasteform in the Waste Handling Building.

IV. Input Data

The input data used to develop the fault tree in Figure 1 is identified in Table 1 below:

Table 1. Fault Tree Input Data

Event Label	Description	Event Probability	Input Value	Reference
G026	Operator Error of Commission in Operating Manual Controls Arranged in Well-Delineated Functional Groups	1.00E-03	1.00E-03	Swain and Guttmann 1983, Table 20-12
G035	Common-Cause Failure of Electrical or Mechanical Component	0.1	0.1	Mosleh et al., p. 3-11
G036	Failure to Follow Written Procedures During Maintenance	1.00E-02	1.00E-02	Swain and Guttmann 1983, Table 20-6
G037	Checker Failure to Detect Error During Maintenance	1.00E-01	1.00E-01	Swain and Guttmann 1983, Table 20-22
G040	Failure to Follow Written Procedures During Maintenance	1.00E-02	1.00E-02	Swain and Guttmann 1983, Table 20-6
G041	Checker Failure to Detect Error During Maintenance	1.00E-01	1.00E-01	Swain and Guttmann 1983, Table 20-22
G042	Common-Cause Failure of Electrical/Mechanical Components	0.1	0.1	Mosleh et al., p. 3-11
G044	Independent, Random Failure of an Active Electrical or Mechanical Component	8.33E-07	5.0E-05 /hr (x 1min/lift ÷ 60 min/hr)	CRWMS M&O 1997, p. 38
G045	Redundant Crane Component Failure	8.33E-07	5.0E-05 /hr (x 1min/lift ÷ 60 min/hr)	CRWMS M&O 1997, p. 38

V. Output

The calculation output illustrated in the fault tree in Figure 1 is based on either multiplication or addition of event probabilities below each “AND” or “OR” gate, respectively. For example, the gate below Event G030 is an “AND” gate, which means that events G036 and G037 are multiplied together to calculate the probability of Event G030. Each of the calculations illustrated in Figure 1 are identified in Table 2 below:

Table 2. Fault Tree Output Probabilities

Event Label	Gate Type	Gate Calculation	Event Probability
G030	AND	G036*G037	1.00E-03
G031	AND	G040*G041	1.00E-03
G028	AND	G030*G031	1.00E-06
G026	OR	G028+G042	1.00E-04
G034	AND	G044*G045	6.94E-13
G050	AND	G026*G051	1.00E-07
G027	OR	G034+G035	8.33E-08
G025	OR	G050+G027	1.83E-07

VI. Conclusion

Based on the fault tree analysis provided herein, the calculated probability of a yoke drop onto SNF in the Waste Handling Building is 1.83E-07. In order to determine the event sequence associated with a specific wasteform (e.g., spent fuel assembly basket), this probability will be multiplied by the applicable number of lifts per year to arrive at the annual frequency of a yoke drop onto SNF. The specific event sequences for a yoke drop onto a spent fuel assembly, spent fuel assembly basket, and spent fuel contained in an unsealed disposal container are included in Attachment VII.

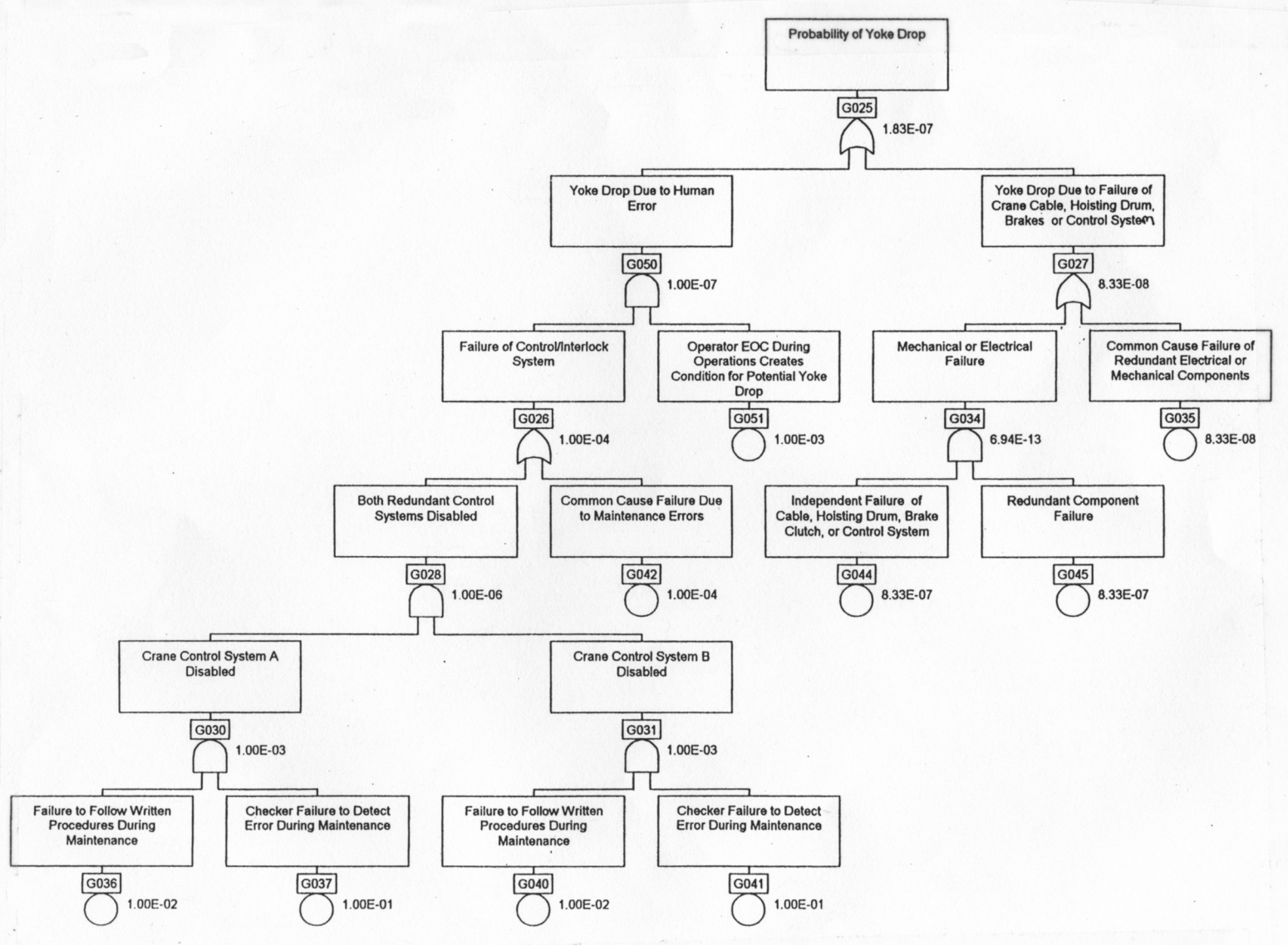


Figure 1. Fault Tree for Probability of Yoke Drop Onto SNF

Attachment VII

Frequency Calculations

The following data contained in this attachment is from file **Frequency Calculations_Rev01.xls** (Attachment I):

Worksheet	Description	Page
Input Data	Input Data and Assumptions Used to Generate Event Frequencies	VII-2
Throughput	Assumed Throughput Rates for Casks, PWR/BWR SFAs and Baskets, and Single Element Canisters	VII-3
Failure Rates	Failure Rates of Components Postulated to Fail During Event Sequences	VII-4
DBEs	Identifies Event Sequences, Material-At-Risk, SSC Failures, Failure Rates, Sequence Frequencies, and DBE Categories	VII-5 to VII-6
Test Cases	Validation Test Cases for Formulas contained in this workbook	VII-7

Input Data & Assumptions		
DCHS:	Value	Basis
Number of unsealed lifts/DCs processed	1	Assumption 3.6
Max # CSNF DCs processed/year	600	Assumption 3.7
ATS Assumptions:	Value	Basis
# of SECs per Basket	4	Assumption 3.8
# of PWR SFAs per Basket	4	Assumption 3.8
# of BWR SFAs per Basket	8	Assumption 3.8
# of Lifts/SFA	4	Assumption 3.9
# of Wet Lifts/SFA	2	Assumption 3.9
# of Dry Lifts/SFA	2	Assumption 3.9
# of Lifts/Basket	6	Assumption 3.10
# of Wet Lifts/Basket	5	Assumption 3.10
# of Dry Lifts/Basket	1	Assumption 3.10
Avg. Time (hrs) per SNF transfer operation (e.g., from cask to staging rack or from staging rack to storage pool)	0.5	Assumption 3.26
# of crane maintenances/year	1	Assumption 3.11
Number of years of WHB operation	30	Assumption 3.12
CCHS Assumptions:	Value	Basis
# of lifts off rail/truck and onto cart	1	Assumption 3.14
# of lifts into/out of the preparation pit	1	Assumption 3.14
# of lifts over pool	1	Assumption 3.14
SEC = Single Element Disposable Canister		
SFA = Spent Fuel Assembly		
ATS = Assembly Transfer System		
CCHS = Cask/Carrier Handling System		

Throughput Data			
Waste Form	Max. Annual Throughput	Fraction of Total	Reference
Peak # shipping casks handled/yr	620	--	(CRWMS M&O 1999a, p. 13)
BWR SFAs/yr	7,800	0.5994	(CRWMS M&O 1999a, p. 14)
PWR SFAs/yr	5,000	0.3842	(CRWMS M&O 1999a, p. 14)
BWR Baskets/yr	975	0.4279	Calculated
PWR Baskets/yr	1,250	0.5486	Calculated
Total PWR/BWR SFAs/yr	12,800	0.9836	Calculated (7800+5000)
Total PWR/BWR SFA Baskets/yr	2,225	0.9766	Calculated (975+1250)
Total failed fuel SECs projected	6,400	1.0000	(CRWMS M&O 1999a, p. 11)
Max. # of BWR SFAs per Basket	8	--	Assumption 3.19
Max. # of PWR SFAs per Basket	4	--	Assumption 3.19
Average failed fuel SECs received per year	213	0.0164	Calculated
# of SECs per basket	4	--	Assumption 3.8
Average # SEC baskets per year	53	0.0234	Calculated
Total CSNF SFAs & Canisters/yr	13,013	1.0	Calculated
Total CSNF (SFAs & Canisters) Baskets/yr	2,278	1.0	Calculated
SEC = Single Element Disposable Canister			
SFA = Spent Fuel Assembly			

Failure Rates/Probabilities:			
System/Structure/Component	**Failure Rate**	**Units**	**Reference**
Fuel assembly/basket transfer machine	1.80E-05	drops/lift	(CRWMS M&O 1997)
Control System failure (all modes)	6.00E-06	failures/hr	(IEEE 1894, p. 573)
Overhead Crane Drop/Lift	1.40E-05	drops/lift	(CRWMS M&O 1998b)
Probability of Lifting Yoke Drop Onto Wasteform	1.83E-07	drops/lift	Attachment VI

ATS Operations:	Event	Event #	Occurs in Pool?	Conditional Probability	Material at Risk (# SFAs)	SSC Failure	Failure Rate	Units	Max # Lifts or Operations per Year	Event Frequency (per year)	HVAC Available?	HVAC Availability	Sequence Frequency (per year)	Event Sequence Category
Lift SFA out of cask in cask unloading pool	SFA Drop Onto Another SFA in Cask	1-01	Y	1.00	2-PWR/2-BWR	WATM	1.80E-05	drops/lift	13,013	2.34E-01	Y	0.9999998	2.34E-01	1
		BDBE-01									N	1.72E-07	4.03E-08	BDBE
Move SFA to basket staging rack	SFA Collision	1-02	Y	1.00	1-PWR/1-BWR	Control System	3.00E-06	failures/operation	13,013	3.90E-02	Y	0.9999998	3.90E-02	1
		BDBE-02									N	1.72E-07	6.71E-09	BDBE
Lower SFA into basket in pool	SFA Drop Onto Empty Basket	1-03	Y	0.18	1-PWR/1-BWR	WATM	1.80E-05	drops/movement	13,013	4.10E-02	Y	0.9999998	4.22E-02	1
		BDBE-03									N	1.72E-07	7.05E-09	BDBE
	SFA Drop Onto Another SFA in Basket	1-04	Y	0.82	2-PWR/2-BWR	WATM	1.80E-05	drops/movement	13,013	1.93E-01	Y	0.9999998	1.92E-01	1
		BDBE-04									N	1.72E-07	3.32E-08	BDBE
Lift basket out of basket staging rack	Basket Drop Onto Another Basket in Basket Staging Rack	1-05	Y	1.00	8-PWR/16-BWR	WATM	1.80E-05	drops/lift	2,278	4.10E-02	Y	0.9999998	4.10E-02	1
		BDBE-05									N	1.72E-07	7.05E-09	BDBE
Move basket to pool storage area	Basket Collision During Transfer to Pool Storage	2-01	Y	1.00	4 PWR / 8 BWR	Control System	3.00E-06	failures/operation	2,278	6.84E-03	Y	0.9999998	6.83E-03	2
		BDBE-06									N	1.72E-07	1.18E-09	BDBE
Lower basket into pool storage area	Basket Drop Onto Another Basket in Pool	1-06	Y	1.00	8-PWR/16-BWR	WATM	1.80E-05	drops/lift	2,278	4.10E-02	Y	0.9999998	4.10E-02	1
		BDBE-07									N	1.72E-07	7.05E-09	BDBE
Lift basket out of pool storage area	Basket Drop Onto Another Basket in Pool	1-07	Y	1.00	8-PWR/16-BWR	WATM	1.80E-05	drops/lift	2,278	4.10E-02	Y	0.9999998	4.10E-02	1
		BDBE-08									N	1.72E-07	7.05E-09	BDBE
Move basket to incline transfer cart	Basket Collision During Transfer to Incline Transfer Canal	2-02	Y	1.00	4 PWR / 8 BWR	Control System	3.00E-06	failures/operation	2,278	6.84E-03	Y	0.9999998	6.83E-03	2
		BDBE-09									N	1.72E-07	1.18E-09	BDBE
Lower basket into incline transfer cart	Basket Drop Onto Transfer Cart or Pool Floor	1-08	Y	1.00	4-PWR/8-BWR	WATM	1.80E-05	drops/movement	2,278	4.10E-02	Y	0.9999998	4.10E-02	1
		BDBE-10									N	1.72E-07	7.05E-09	BDBE
Move basket up incline transfer canal	Uncontrolled Descent of Incline Transfer Cart	2-03	Y	1.00	4-PWR/8-BWR	Incline Transfer Cart	3.00E-06	failures/operation	2,278	6.84E-03	Y	0.9999998	6.83E-03	2
		BDBE-11									N	1.72E-07	1.18E-09	BDBE
Lift basket off incline transfer cart into DATM	Basket Drop Back Into Pool	1-09	Y	1.00	4-PWR/8-BWR	DATM	1.80E-05	drops/lift	2,278	4.10E-02	Y	0.9999998	4.10E-02	1
		BDBE-12									N	1.72E-07	7.05E-09	BDBE
Move basket to dryer	Basket Drop Onto ATS Hot Cell Floor	1-10	N	1.00	4-PWR/8-BWR	DATM	1.80E-05	drops/lift	2,278	4.10E-02	Y	0.9999998	4.10E-02	1
		BDBE-13									N	1.72E-07	7.05E-09	BDBE
Lower basket from DATM to dryer	Basket Drop Onto Another Basket in Dryer	1-11	N	1.00	8-PWR/16-BWR	DATM	1.80E-05	drops/lift	2,278	4.10E-02	Y	0.9999998	4.10E-02	1
		BDBE-14									N	1.72E-07	7.05E-09	BDBE
Lift individual SFA out of dryer	SFA Drop Onto Another SFA in Dryer	1-12	N	1.00	2-PWR/2-BWR	DATM	1.80E-05	drops/lift	13,013	2.34E-01	Y	0.9999998	2.34E-01	1
		BDBE-15									N	1.72E-07	4.03E-08	BDBE
Move SFA to DC	SFA Drop Onto ATS Hot Cell Floor	1-13	N	1.00	1-PWR/1-BWR	DATM	1.80E-05	drops/lift	13,013	2.34E-01	Y	0.9999998	2.34E-01	1
		BDBE-16									N	1.72E-07	4.03E-08	BDBE
Lower SFA into DC	SFA Drop Onto Another SFA in DC	1-14	N	1.00	2-PWR/2-BWR	DATM	1.80E-05	drops/lift	13,013	2.34E-01	Y	0.9999998	2.34E-01	1
		BDBE-17									N	1.72E-07	4.03E-08	BDBE
All SFA Lifts	Handling Equipment Drop Onto SFA in Pool	2-04	Y	0.50	1-PWR/1-BWR	Handling Equipment [1]	1.83E-07	drops/lift [2]	26,027	2.38E-03	Y	0.9999998	2.38E-03	2
		BDBE-18									N	1.72E-07	4.10E-10	BDBE
	Handling Equipment Drop Onto SFA in Hot Cell	2-05	N	0.50	1-PWR/1-BWR	Handling Equipment [1]	1.83E-07	drops/lift [2]	26,027	2.38E-03	Y	0.9999998	2.38E-03	2
		BDBE-19									N	1.72E-07	4.10E-10	BDBE
All Basket Lifts	Handling Equipment Drop Onto SFA Basket in Pool	2-06	Y	0.83	4-PWR/8-BWR	Handling Equipment [1]	1.83E-07	drops/lift [2]	11,392	1.74E-03	Y	0.9999998	1.74E-03	2
		BDBE20									N	1.72E-07	2.99E-10	BDBE
	Handling Equipment Drop Onto SFA Basket in Hot Cell	2-07	N	0.17	4-PWR/8-BWR	Handling Equipment [1]	1.83E-07	drops/lift [2]	2,278	6.95E-05	Y	0.9999998	6.95E-05	2
		BDBE-22									N	1.72E-07	1.20E-11	BDBE

DC Handling Operations:	Event	Event #	Occurs in Pool?	Conditional Probability	Material at Risk (# SFAs)	SSC Failure	Failure Rate	Units	Max # Lifts or Movements per Year	Event Frequency (per year)	HVAC Available?	HVAC Availability	Sequence Frequency (per year)	Event Sequence Category
Transfer unsealed DC from ATS to DC Handling Cell	Unsealed DC Collision	2-08	N	1.00	21-PWR/44-BWR	Control System	3.00E-06	failures/movement	600	1.80E-03	Y	0.9999998	1.80E-03	2
		BDBE-23									N	1.72E-07	3.10E-10	BDBE
Lift unsealed DC onto welding turntable	Unsealed DC Drop and Slapdown	2-09	N	1.00	21-PWR/44-BWR	DC Bridge Crane	1.40E-05	drops/lift	600	8.40E-03	Y	0.9999998	8.40E-03	2
		BDBE-24									N	1.72E-07	1.44E-09	BDBE
	Handling Equipment Drop Onto Unsealed DC	2-10	N	1.00	21-PWR/44-BWR	Handling Equipment [1]	1.83E-07	drops/lift [2]	600	1.10E-04	Y	0.9999998	1.10E-04	2
		BDBE-25									N	1.72E-07	1.89E-11	BDBE
Cask Handling Operations:														
Upright cask and lift off truck/rail and onto transfer cart	Shipping Cask Drop Onto Floor (no impact limiters) [4]	BDBE-26	N	1.00	24-PWR/68-BWR	Control System	1.40E-05	failures/movement	620	8.68E-03	Y	0.9999998	8.68E-03	2
		BDBE-27									N	1.72E-07	1.49E-09	BDBE
Move cask to Cask Preparation Pit	Shipping Cask Tipover (no impact limiters) [4]	BDBE-28	N	1.00	24-PWR/68-BWR	Bridge Crane	1.40E-05	drops/lift	620	8.68E-03	Y	0.9999998	8.68E-03	2
		BDBE-29									N	1.72E-07	1.49E-09	BDBE
Lower sealed cask into, then lift unsealed cask out of, Cask Prep. Pit	Shipping Cask Drop Into Cask Preparation Pit [5]	2-11	N	0.50	24-PWR/68-BWR	Bridge Crane	1.40E-05	drops/lift	1,240	8.68E-03	Y	0.9999998	8.68E-03	2
		BDBE-30									N	1.72E-07	1.49E-09	BDBE
Lower cask into Cask Unloading Pool	Shipping Cask Drop Into Cask Unloading Pool [6]	2-12	Y	1.00	24-PWR/68-BWR	Bridge Crane	1.40E-05	drops/lift	620	8.68E-03	Y	0.9999998	8.68E-03	2
		BDBE-31									N	1.72E-07	1.49E-09	BDBE
All cask handling operations in Carrier Bay, ATS or CTS	Non-Mechanistic Release of Radioactive Gases in Shipping Cask [3]	NM-01	N	1.00	24-PWR/68-BWR	N/A	N/A	N/A	N/A	N/A	N/A	N/A	NM [3]	NM [3]

Subsurface Events	Event #	Occurs in Pool?	Conditional Probability	Material at Risk (# SFAs)	SSC Failure	Event Category
Non-Mechanistic Release of Radioactive Gas Inventory Due to Preclosure Early Failure of a WP [7]	NM-02	N	1.00	21-PWR/44-BWR	Waste Package	NM [7]

External Events & Natural Phenomena:

None considered. It's assumed that the MGR will be designed to withstand all credible external events and natural phenomena that could potentially result in a release.

WATM = Wet Assembly Transfer Machine
DATM = Dry Assembly Transfer Machine

LEGEND:
Green shading indicates non-mechanistic event
Yellow shading indicates Cat. 1 event
Blue shading indicates Cat. 2 event
Purple shading indicates Beyond Design Basis Event

Notes:
(1) Presumed to result in the fall of a lifting yoke that impacts SNF; due to a combination of human error and failure of a crane cable, hoisting drum, brake, or control system (see Attachment VI).
(2) See Attachment VI for the fault tree used to construct this drop probability.
(3) A non-mechanistic release was assumed without a frequency analysis. The MGR is designed to prevent a credible breach of a sealed shipping cask (Assumption 3.15).
(4) Conditional probability of a CSNF cask breach given a drop from the normal lift height is zero (Assumption 3.15)
(5) Half the lifts involve lowering a sealed shipping cask into the Cask Prep. Pit; the other half involve raising an unsealed cask out of the Cask Prep. Pit. Only drops of the unsealed cask back into the Pit are assumed to result in a release.
(6) Casks being lowered into the Cask Unloading Pool are not sealed (i.e., lid bolts have been removed), thus all drops result in a release.
(7) A non-mechanistic release was assumed without a frequency analysis. The MGR is designed to prevent a credible breach of a sealed WP (Assumption 3.15).

Validation Test Cases for Formulas Contained in this Workbook

Worksheet	Cell Range	Test Cell	Formula	Input	Output	Hand-Calculated Results*
Throughput	C7	C7	=C5/8	C5=7800	C7=975	C7=975
Throughput	C8	C8	=C6/4	C6=5000	C8=1250	C8=1250
Throughput	C14	C14	=C11/'Input Data'!B22	C11=6400, Input Data!B22=30	C12=213	C12=213.33
Throughput	C16	C16	=C14/C15	C14=213, C15=4	C16=53	C16=53.25
Throughput	C17	C17	=C9+C14	C9=12800, C14=213	C17=13013	C17=13013
Throughput	C18	C18	=C7+C8+C16	C7=975, C8=1250, C16=53	C18=2278	C18=2278
DBEs	E6	E6	=(Throughput!C5/Throughput!C17)*1/Throughput!C12+(Throughput!C6/Throughput!C17)*1/Throughput!C13+(Throughput!C14/Throughput!C17)*1/Throughput!C15	C5=7800, C17=13013, C12=8, C6=5000, C13=4, C14=213, C15=4	E6=0.175	E6=0.18
DBEs	E8	E8	=1-E6	E6=.175	E8=.825	E8=.82
DBEs	H4, H12, H18, H22, H46, H54	H4	='Failure Rates'!$B$6*'Input Data'!$B$19	Failure Rates!B6=6.0E-6, Input Data!B19=0.5	H4=3.0E-6	H4=3.00E-6
DBEs	J58, J60	J58	=Throughput!C4*'Input Data'!B26*2	Throughput!C4=620, Input Data!B26=1	J58=1240	J58=1240
DBEs	M2:M60 (cells with HVAC Available)	M2	=1-M3	M3=1.72E-7	M2=0.9999998	M2=0.9999998
DBEs	N2:N61	N2	=E2*H2*J2*M2	E2=1, H2=1.8E-5, J2=13013, M2=0.9999998	N2=2.34E-1	N2=0.2342

* Output values may differ slightly from hand calculations due to rounding errors. These differences are acceptable for the range of input values used in this calculation.

Attachment VIII

SR Source Term Calculations

The following data contained in this attachment is from file **SR Source Terms_Rev01.xls** (Attachment I):

Worksheet	Description	Page
INHAL. DCFs	Inhalation Dose Conversion Factors (DCFs)	VIII-2
Avg_PWR Inv	Average PWR Inventory	VIII-3
Max_PWR Inv	Maximum PWR Inventory	VIII-4
Avg_BWR Inv	Average BWR Inventory	VIII-5
Max_BWR Inv	Maximum BWR Inventory	VIII-6
Avg_PWR Dose	Average PWR Inhalation Dose Calculations	VIII-7
Max_PWR Dose	Maximum PWR Inhalation Dose Calculations	VIII-8
Avg_BWR Dose	Average BWR Inhalation Dose Calculations	VIII-9
Max_BWR Dose	Maximum BWR Inhalation Dose Calculations	VIII-10
Submersion Dose	Air Submersion Dose Calculations	VIII-11
Test Cases	Validation Test Cases for Formulas Contained in this workbook	VIII-12

Inhalation Dose Conversion Factors from Federal Guidance Report #11 (Eckerman et al. 1988 Table 2.1)

* Isotope list from DOE/SNF/REP-024, Methodology for DOE Spent Nuclear Fuel Source Term Determination

D = Daily, W = Weekly, Y = Yearly

Isotope*	Lung Clearance Class Used	Gonad (Sv/Bq)	Breast (Sv/Bq)	Lung (Sv/Bq)	R Marrow (Sv/Bq)	B Surface (Sv/Bq)	Thyroid (Sv/Bq)	Remainder (Sv/Bq)	Whole Body (Sv/Bq)
Ac-227	Y	3.56E-05	1.06E-08	1.54E-03	2.33E-04	2.91E-03	6.47E-09	1.34E-04	3.49E-04
Am-241	W	3.25E-05	2.67E-09	1.84E-05	1.74E-04	2.17E-03	1.60E-09	7.82E-05	1.20E-04
Am-242m	W	3.21E-05	1.38E-09	4.20E-06	1.69E-04	2.12E-03	5.64E-10	7.48E-05	1.15E-04
Am-243	W	3.26E-05	1.52E-08	1.78E-05	1.73E-04	2.17E-03	8.29E-09	7.74E-05	1.19E-04
C-14	CO2	6.36E-12	6.36E-12	6.36E-12	6.36E-12	6.36E-12	6.36E-12	6.36E-12	6.36E-12
Cd-113m	Y	4.72E-09	4.72E-09	4.09E-07	4.72E-09	4.72E-09	4.72E-09	1.86E-07	1.08E-07
Cl-36	W	5.04E-10	5.04E-10	4.56E-08	5.04E-10	5.04E-10	5.04E-10	5.36E-10	5.93E-09
Cm-242	W	5.70E-07	9.44E-10	1.55E-05	3.90E-06	4.87E-05	9.41E-10	2.45E-06	4.67E-06
Cm-243	W	2.07E-05	6.29E-09	1.94E-05	1.18E-04	1.47E-03	3.83E-09	5.76E-05	8.30E-05
Cm-244	W	1.59E-05	1.04E-09	1.93E-05	9.38E-05	1.17E-03	1.01E-09	4.78E-05	6.70E-05
Cm-245	W	3.37E-05	6.69E-09	1.80E-05	1.79E-04	2.24E-03	3.68E-09	7.96E-05	1.23E-04
Cm-246	W	3.34E-05	4.00E-09	1.82E-05	1.78E-04	2.22E-03	2.26E-09	7.94E-05	1.22E-04
Co-60	Y	4.76E-09	1.84E-08	3.45E-07	1.72E-08	1.35E-08	1.62E-08	3.60E-08	5.91E-08
Cs-134	D	1.30E-08	1.08E-08	1.18E-08	1.18E-08	1.10E-08	1.11E-08	1.39E-08	1.25E-08
Cs-135	D	1.20E-09	1.20E-09	1.41E-09	1.20E-09	1.20E-09	1.20E-09	1.20E-09	1.23E-09
Cs-137	D	8.76E-09	7.84E-09	8.82E-09	8.30E-09	7.94E-09	7.93E-09	9.12E-09	8.63E-09
Eu-154	W	1.17E-08	1.55E-08	7.92E-08	1.06E-07	5.23E-07	7.14E-09	1.13E-07	7.73E-08
Eu-155	W	3.56E-10	6.14E-10	1.19E-08	1.43E-08	1.52E-07	2.40E-10	1.11E-08	1.12E-08
Fe-55	W	1.79E-10	1.74E-10	1.06E-09	1.76E-10	1.75E-10	1.85E-10	4.37E-10	3.61E-10
H-3	V	1.73E-11	1.73E-11	1.73E-11	1.73E-11	1.73E-11	1.73E-11	1.73E-11	1.73E-11
I-129	D	8.69E-11	2.09E-10	3.14E-10	1.40E-10	1.38E-10	1.56E-06	1.18E-10	4.69E-08
Kr-85		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nb-93m	Y	1.55E-10	4.36E-11	6.45E-08	1.14E-10	2.84E-10	1.14E-11	3.04E-10	7.90E-09
Nb-94	Y	4.42E-09	2.24E-08	7.48E-07	2.26E-08	1.97E-08	2.22E-08	4.45E-08	1.12E-07
Ni-59	W	1.09E-10	1.05E-10	1.20E-09	1.06E-10	1.05E-10	1.14E-10	1.40E-10	2.48E-10
Ni-63	W	2.47E-10	2.47E-10	3.07E-09	2.47E-10	2.47E-10	2.47E-10	3.67E-10	6.22E-10
Np-237	W	2.96E-05	1.69E-08	1.61E-05	2.62E-04	3.27E-03	1.34E-08	2.34E-05	1.46E-04
Pa-231	Y	3.06E-09	5.65E-09	7.47E-04	2.88E-04	3.60E-03	4.45E-09	2.12E-07	2.32E-04
Pb-210	D	3.18E-07	3.18E-07	3.18E-07	3.75E-06	5.47E-05	3.18E-07	4.69E-06	3.67E-06
Pd-107	Y	1.05E-13	1.05E-13	2.85E-08	5.68E-13	1.51E-12	1.05E-13	9.71E-11	3.45E-09
Pm-147	Y	8.25E-15	3.60E-14	7.74E-08	1.61E-09	2.01E-08	1.98E-14	1.56E-09	1.06E-08
Pu-238	Y	1.04E-05	4.40E-10	3.20E-04	5.80E-05	7.25E-04	3.86E-10	2.74E-05	7.79E-05
Pu-239	Y	1.20E-05	3.99E-10	3.23E-04	6.57E-05	8.21E-04	3.75E-10	3.02E-05	8.33E-05
Pu-240	Y	1.20E-05	4.33E-10	3.23E-04	6.57E-05	8.21E-04	3.76E-10	3.02E-05	8.33E-05
Pu-241	Y	2.76E-07	2.14E-11	3.18E-06	1.43E-06	1.78E-05	9.15E-12	6.02E-07	1.34E-06
Pu-242	Y	1.14E-05	4.35E-10	3.07E-04	6.25E-05	7.81E-04	3.71E-10	2.86E-05	7.92E-05
Ra-226	W	1.02E-07	1.02E-07	1.61E-05	6.64E-07	7.59E-06	1.02E-07	1.07E-07	2.32E-06
Ra-228	W	1.83E-07	1.84E-07	7.22E-06	7.38E-07	6.51E-06	1.83E-07	1.87E-07	1.29E-06
Ru-106	Y	1.30E-09	1.78E-09	1.04E-06	1.76E-09	1.61E-09	1.72E-09	1.20E-08	1.29E-07
Sb-125	W	3.60E-10	4.16E-10	2.17E-08	5.35E-10	9.78E-10	3.24E-10	1.45E-09	3.30E-09
Se-79	W	5.98E-10	5.98E-10	9.81E-09	5.98E-10	5.98E-10	5.98E-10	3.77E-09	2.66E-09
Sm-147	W	0.00E+00	0.00E+00	7.26E-06	2.75E-05	3.44E-04	0.00E+00	1.89E-05	2.02E-05
Sm-151	W	4.03E-14	1.49E-13	3.26E-09	1.10E-08	1.38E-07	1.32E-14	7.51E-09	8.10E-09
Sn-126	W	4.95E-09	5.39E-09	1.51E-07	1.69E-08	3.33E-08	4.90E-09	1.20E-08	2.69E-08
Sr-90	D	2.64E-09	2.64E-09	3.73E-09	3.36E-07	7.27E-07	2.64E-09	3.36E-09	6.47E-08
Tc-99	W	3.99E-11	3.99E-11	1.67E-08	3.99E-11	3.99E-11	1.07E-09	6.26E-10	2.25E-09
Th-229	Y	1.18E-06	1.18E-06	1.99E-03	4.60E-04	5.73E-03	1.18E-06	3.02E-06	4.67E-04
Th-230	Y	1.72E-07	1.72E-07	3.00E-04	6.99E-05	8.71E-04	1.72E-07	4.48E-07	7.07E-05
Th-232	Y	5.98E-07	6.14E-07	9.40E-04	4.01E-04	4.99E-03	5.99E-07	1.51E-06	3.11E-04
U-232	Y	1.69E-08	2.66E-08	1.48E-03	4.68E-07	7.14E-06	2.43E-08	5.86E-07	1.78E-04
U-233	Y	2.69E-09	2.73E-09	3.04E-04	7.39E-08	1.16E-06	2.70E-09	1.08E-07	3.66E-05
U-234	Y	2.65E-09	2.68E-09	2.98E-04	7.22E-08	1.13E-06	2.65E-09	1.06E-07	3.58E-05
U-235	Y	2.84E-09	5.37E-09	2.76E-04	7.15E-08	1.05E-06	4.11E-09	1.02E-07	3.32E-05
U-236	Y	2.51E-09	2.54E-09	2.82E-04	6.83E-08	1.07E-06	2.51E-09	1.19E-09	3.39E-05
U-238	Y	2.42E-09	2.91E-09	2.66E-04	6.88E-08	1.01E-06	2.73E-09	9.61E-08	3.20E-05
Zr-93	W	5.58E-12	1.20E-11	3.30E-09	4.49E-08	5.54E-07	4.45E-12	1.54E-10	2.25E-08

Average PWR Assembly
Enrichment = 4.0%, Burnup: 48 GWd/MTU, Age = 25 years

Nuclide	Curies/FA
Ac-227	1.61E-05
Am-241	1.98E+03
Am-242m	6.39E+00
Am-243	2.20E+01
C-14	3.32E-01
Cd-113m	7.66E+00
Cl-36	6.80E-03
Cm-242	5.27E+00
Cm-243	1.03E+01
Cm-244	1.36E+03
Cm-245	3.07E-01
Cm-246	1.04E-01
Co-60	3.13E+02
Cs-134	2.52E+01
Cs-135	3.50E-01
Cs-137	4.11E+04
Eu-154	6.71E+02
Eu-155	5.16E+01
Fe-55	3.47E+00
H-3	1.14E+02
I-129	2.20E-02
Kr-85	1.13E+03
Nb-93m	1.30E+01
Nb-94	8.39E-01
Ni-59	2.09E+00
Ni-63	2.52E+02
Np-237	2.47E-01
Pa-231	2.97E-05
Pb-210	0.00E+00
Pd-107	8.41E-02
Pm-147	1.19E+02
Pu-238	2.29E+03
Pu-239	1.77E+02
Pu-240	3.18E+02
Pu-241	2.47E+04
Pu-242	1.64E+00
Ra-226	0.00E+00
Ra-228	0.00E+00
Ru-106	1.23E-02
Sb-125	9.71E+00
Se-79	4.57E-02
Sm-147	0.00E+00
Sm-151	2.11E+02
Sn-126	3.85E-01
Sr-90	2.72E+04
Tc-99	8.99E+00
Th-229	0.00E+00
Th-230	1.48E-04
Th-232	0.00E+00
U-232	2.05E-02
U-233	4.07E-05
U-234	6.77E-01
U-235	7.36E-03
U-236	1.72E-01
U-238	1.48E-01
Zr-93	8.94E-01

Maximum PWR Assembly
Enrichment = 5.0%, Burnup: 75 GWd/MTU, Age = 5 years

Nuclide	Curies/FA
Ac-227	0.00E+00
Am-241	8.71E+02
Am-242m	1.02E+01
Am-243	5.22E+01
C-14	4.89E-01
Cd-113m	3.82E+01
Cl-36	9.69E-03
Cm-242	3.43E+01
Cm-243	3.83E+01
Cm-244	1.12E+04
Cm-245	1.41E+00
Cm-246	8.38E-01
Co-60	5.66E+03
Cs-134	3.72E+04
Cs-135	5.99E-01
Cs-137	9.87E+04
Eu-154	5.77E+03
Eu-155	1.68E+03
Fe-55	6.84E+02
H-3	4.72E+02
I-129	3.38E-02
Kr-85	5.63E+03
Nb-93m	4.54E+01
Nb-94	1.27E+00
Ni-59	2.78E+00
Ni-63	4.16E+02
Np-237	3.85E-01
Pa-231	4.25E-05
Pb-210	0.00E+00
Pd-107	1.45E-01
Pm-147	2.34E+04
Pu-238	6.16E+03
Pu-239	1.85E+02
Pu-240	3.90E+02
Pu-241	7.91E+04
Pu-242	3.01E+00
Ra-226	0.00E+00
Ra-228	0.00E+00
Ru-106	1.27E+04
Sb-125	2.05E+03
Se-79	6.95E-02
Sm-147	0.00E+00
Sm-151	3.13E+02
Sn-126	6.28E-01
Sr-90	6.30E+04
Tc-99	1.28E+01
Th-229	0.00E+00
Th-230	3.56E-05
Th-232	0.00E+00
U-232	5.31E-02
U-233	2.42E-05
U-234	5.46E-01
U-235	4.15E-03
U-236	2.24E-01
U-238	1.43E-01
Zr-93	1.33E+00

Average BWR Assembly
Enrichment = 3.5%, Burnup: 40 GWd/MTU, Age = 25 years

Nuclide	Curies/FA
Ac-227	0.00E+00
Am-241	5.58E+02
Am-242m	2.17E+00
Am-243	5.35E+00
C-14	1.75E-01
Cd-113m	2.26E+00
Cl-36	2.93E-03
Cm-242	1.79E+00
Cm-243	2.48E+00
Cm-244	2.56E+02
Cm-245	4.04E-02
Cm-246	1.45E-02
Co-60	4.40E+01
Cs-134	6.32E+00
Cs-135	1.39E-01
Cs-137	1.39E+04
Eu-154	1.80E+02
Eu-155	1.64E+01
Fe-55	1.09E+00
H-3	3.95E+01
I-129	7.43E-03
Kr-85	3.81E+02
Nb-93m	4.74E-01
Nb-94	1.87E-02
Ni-59	5.03E-01
Ni-63	5.87E+01
Np-237	6.89E-02
Pa-231	1.39E-05
Pb-210	0.00E+00
Pd-107	2.65E-02
Pm-147	3.98E+01
Pu-238	5.85E+02
Pu-239	5.35E+01
Pu-240	1.14E+02
Pu-241	6.78E+03
Pu-242	5.09E-01
Ra-226	0.00E+00
Ra-228	0.00E+00
Ru-106	3.00E-03
Sb-125	2.89E+00
Se-79	1.59E-02
Sm-147	0.00E+00
Sm-151	5.39E+01
Sn-126	1.27E-01
Sr-90	9.54E+03
Tc-99	3.20E+00
Th-229	0.00E+00
Th-230	6.09E-05
Th-232	0.00E+00
U-232	4.64E-03
U-233	1.14E-05
U-234	2.49E-01
U-235	2.62E-03
U-236	6.26E-02
U-238	6.32E-02
Zr-93	3.38E-01

Maximum BWR Assembly
Enrichment = 5.0%, Burnup: 75 GWd/MTU, Age = 5 years

Nuclide	Curies/FA
Ac-227	0.00E+00
Am-241	2.66E+02
Am-242m	3.40E+00
Am-243	1.93E+01
C-14	3.16E-01
Cd-113m	1.39E+01
Cl-36	4.99E-03
Cm-242	1.13E+01
Cm-243	1.12E+01
Cm-244	3.95E+03
Cm-245	3.54E-01
Cm-246	2.97E-01
Co-60	8.56E+02
Cs-134	1.16E+04
Cs-135	2.82E-01
Cs-137	3.87E+04
Eu-154	1.83E+03
Eu-155	6.37E+02
Fe-55	2.35E+02
H-3	1.76E+02
I-129	1.36E-02
Kr-85	2.03E+03
Nb-93m	1.22E+00
Nb-94	3.39E-02
Ni-59	7.80E-01
Ni-63	1.16E+02
Np-237	1.33E-01
Pa-231	2.94E-05
Pb-210	0.00E+00
Pd-107	5.70E-02
Pm-147	7.46E+03
Pu-238	2.11E+03
Pu-239	5.36E+01
Pu-240	1.48E+02
Pu-241	2.25E+04
Pu-242	1.26E+00
Ra-226	0.00E+00
Ra-228	0.00E+00
Ru-106	3.29E+03
Sb-125	6.21E+02
Se-79	2.89E-02
Sm-147	0.00E+00
Sm-151	8.22E+01
Sn-126	2.52E-01
Sr-90	2.52E+04
Tc-99	5.35E+00
Th-229	0.00E+00
Th-230	2.05E-05
Th-232	0.00E+00
U-232	2.00E-02
U-233	0.00E+00
U-234	2.26E-01
U-235	9.40E-04
U-236	9.55E-02
U-238	6.07E-02
Zr-93	6.03E-01

Inhalation Dose
Average PWR Assembly
Inhalation Dose Conversion Factors from Federal Guidance Report #11 (Eckerman et al. 1988 Table 2.1)

		Gonad DCF		Breast DCF		Lung DCF		R Marrow DCF		Bone Surface DCF		Thyroid DCF		Remainder DCF		Whole Body DCF	
Nuclide	Curies/FA	(Sv/Bq)	Rem/FA	(Sv/Bq)	Rem/FA	(Sv/Bq)	Rem/FA	(Sv/Bq)	Rem/FA	(Sv/Bq)	Rem/FA	(Sv/Bq)	Rem/FA	(Sv/Bq)	Rem/FA	(Sv/Bq)	Rem/FA
Ac-227	1.61E-05	3.56E-05	2.12E+03	1.06E-08	6.31E-01	1.54E-03	9.17E+04	2.33E-04	1.39E+04	2.91E-03	1.73E+05	6.47E-09	3.85E-01	1.34E-04	7.98E+03	3.49E-04	2.08E+04
Am-241	1.98E+03	3.25E-05	2.38E+11	2.67E-09	1.96E+07	1.84E-05	1.35E+11	1.74E-04	1.27E+12	2.17E-03	1.59E+13	1.60E-09	1.17E+07	7.82E-05	5.73E+11	1.20E-04	8.77E+11
Am-242m	6.39E+00	3.21E-05	7.59E+08	1.38E-09	3.26E+04	4.20E-06	9.93E+07	1.69E-04	4.00E+09	2.12E-03	5.01E+10	5.64E-10	1.33E+04	7.48E-05	1.77E+09	1.15E-04	2.72E+09
Am-243	2.20E+01	3.26E-05	2.65E+09	1.52E-08	1.24E+06	1.78E-05	1.45E+09	1.73E-04	1.41E+10	2.17E-03	1.77E+11	8.29E-09	6.75E+05	7.74E-05	6.30E+09	1.19E-04	9.72E+09
C-14	3.32E-01	6.36E-12	7.81E+00	6.36E-12	7.81E+00	6.36E-12	7.81E+00	6.36E-12	7.81E+00	6.36E-12	7.81E+00	6.36E-12	7.81E+00	6.36E-12	7.81E+00	6.36E-12	7.81E+00
Cd-113m	7.66E+00	4.72E-09	1.34E+05	4.72E-09	1.34E+05	4.09E-07	1.16E+07	4.72E-09	1.34E+05	4.72E-09	1.34E+05	4.72E-09	1.34E+05	1.86E-07	5.27E+06	1.08E-07	3.05E+06
Cl-36	6.80E-03	5.04E-10	1.27E+01	5.04E-10	1.27E+01	4.56E-08	1.15E+03	5.04E-10	1.27E+01	5.04E-10	1.27E+01	5.04E-10	1.27E+01	5.36E-10	1.35E+01	5.93E-09	1.49E+02
Cm-242	5.27E+00	5.70E-07	1.11E+07	9.44E-10	1.84E+04	1.55E-05	3.02E+08	3.90E-06	7.60E+07	4.87E-05	9.50E+08	9.41E-10	1.83E+04	2.45E-06	4.78E+07	4.67E-06	9.10E+07
Cm-243	1.03E+01	2.07E-05	7.89E+08	6.29E-09	2.40E+05	1.94E-05	7.39E+08	1.18E-04	4.50E+09	1.47E-03	5.60E+10	3.83E-09	1.46E+05	5.76E-05	2.20E+09	8.30E-05	3.16E+09
Cm-244	1.36E+03	1.59E-05	8.00E+10	1.04E-09	5.23E+06	1.93E-05	9.71E+10	9.38E-05	4.72E+11	1.17E-03	5.89E+12	1.01E-09	5.08E+06	4.78E-05	2.41E+11	6.70E-05	3.37E+11
Cm-245	3.07E-01	3.37E-05	3.83E+07	6.69E-09	7.60E+03	1.80E-05	2.04E+07	1.79E-04	2.03E+08	2.24E-03	2.54E+09	3.68E-09	4.18E+03	7.96E-05	9.04E+07	1.23E-04	1.40E+08
Cm-246	1.04E-01	3.34E-05	1.29E+07	4.00E-09	1.54E+03	1.82E-05	7.00E+06	1.78E-04	6.85E+07	2.22E-03	8.54E+08	2.26E-09	8.70E+02	7.94E-05	3.06E+07	1.22E-04	4.71E+07
Co-60	3.13E+02	4.76E-09	5.51E+06	1.84E-08	2.13E+07	3.45E-07	4.00E+08	1.72E-08	1.99E+07	1.35E-08	1.56E+07	1.62E-08	1.88E+07	3.60E-08	4.17E+07	5.91E-08	6.84E+07
Cs-134	2.52E+01	1.30E-08	1.21E+06	1.08E-08	1.01E+06	1.18E-08	1.10E+06	1.18E-08	1.10E+06	1.10E-08	1.03E+06	1.11E-08	1.03E+06	1.39E-08	1.30E+06	1.25E-08	1.17E+06
Cs-135	3.50E-01	1.20E-09	1.55E+03	1.20E-09	1.55E+03	1.41E-09	1.83E+03	1.20E-09	1.55E+03	1.20E-09	1.55E+03	1.20E-09	1.55E+03	1.20E-09	1.55E+03	1.23E-09	1.59E+03
Cs-137	4.11E+04	8.76E-09	1.33E+09	7.84E-09	1.19E+09	8.82E-09	1.34E+09	8.30E-09	1.26E+09	7.94E-09	1.21E+09	7.93E-09	1.21E+09	9.12E-09	1.39E+09	8.63E-09	1.31E+09
Eu-154	6.71E+02	1.17E-08	2.90E+07	1.55E-08	3.85E+07	7.92E-08	1.97E+08	1.06E-07	2.63E+08	5.23E-07	1.30E+09	7.14E-09	1.77E+07	1.13E-07	2.81E+08	7.73E-08	1.92E+08
Eu-155	5.16E+01	3.56E-10	6.80E+04	6.14E-10	1.17E+05	1.19E-08	2.27E+06	1.43E-08	2.73E+06	1.52E-07	2.90E+07	2.40E-10	4.58E+04	1.11E-08	2.12E+06	1.12E-08	2.14E+06
Fe-55	3.47E+00	1.79E-10	2.30E+03	1.74E-10	2.23E+03	1.06E-09	1.36E+04	1.76E-10	2.26E+03	1.75E-10	2.25E+03	1.85E-10	2.38E+03	4.37E-10	5.61E+03	3.61E-10	4.64E+03
H-3	1.14E+02	1.73E-11	7.30E+03	1.73E-11	7.30E+03	1.73E-11	7.30E+03	1.73E-11	7.30E+03	1.73E-11	7.30E+03	1.73E-11	7.30E+03	1.73E-11	7.30E+03	1.73E-11	7.30E+03
I-129	2.20E-02	8.69E-11	7.07E+00	2.09E-10	1.70E+01	3.14E-10	2.56E+01	1.40E-10	1.14E+01	1.38E-10	1.12E+01	1.56E-06	1.27E+05	1.18E-10	9.61E+00	4.69E-08	3.82E+03
Kr-85	1.13E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nb-93m	1.30E+01	1.55E-10	7.46E+03	4.36E-11	2.10E+03	6.45E-08	3.10E+06	1.14E-10	5.48E+03	2.84E-10	1.37E+04	1.14E-11	5.48E+02	3.04E-10	1.46E+04	7.90E-09	3.80E+05
Nb-94	8.39E-01	4.42E-09	1.37E+04	2.24E-08	6.95E+04	7.48E-07	2.32E+06	2.26E-08	7.02E+04	1.97E-08	6.12E+04	2.22E-08	6.89E+04	4.45E-08	1.38E+05	1.12E-07	3.46E+05
Ni-59	2.09E+00	1.09E-10	8.43E+02	1.05E-10	8.12E+02	1.20E-09	9.28E+03	1.06E-10	8.20E+02	1.05E-10	8.12E+02	1.14E-10	8.82E+02	1.40E-10	1.08E+03	2.48E-10	1.92E+03
Ni-63	2.52E+02	2.47E-10	2.30E+05	2.47E-10	2.30E+05	3.07E-09	2.86E+06	2.47E-10	2.30E+05	2.47E-10	2.30E+05	2.47E-10	2.30E+05	3.67E-10	3.42E+05	6.22E-10	5.80E+05
Np-237	2.47E-01	2.96E-05	2.71E+07	1.69E-08	1.54E+04	1.61E-05	1.47E+07	2.62E-04	2.39E+08	3.27E-03	2.99E+09	1.34E-08	1.22E+04	2.34E-05	2.14E+07	1.46E-04	1.33E+08
Pa-231	2.97E-05	3.06E-09	3.36E-01	5.65E-09	6.21E-01	7.47E-04	8.21E+04	2.88E-04	3.16E+04	3.60E-03	3.96E+05	4.45E-09	4.89E-01	2.12E-07	2.33E+01	2.32E-04	2.55E+04
Pb-210	0.00E+00	3.18E-07	0.00E+00	3.18E-07	0.00E+00	3.18E-07	0.00E+00	3.75E-06	0.00E+00	5.47E-05	0.00E+00	3.18E-07	0.00E+00	4.69E-06	0.00E+00	3.67E-06	0.00E+00
Pd-107	8.41E-02	1.05E-13	3.27E-02	1.05E-13	3.27E-02	2.85E-08	8.87E+03	5.68E-13	1.77E-01	1.51E-12	4.70E-01	1.05E-13	3.27E-02	9.71E-11	3.02E+01	3.45E-09	1.07E+03
Pm-147	1.19E+02	8.25E-15	3.63E+00	3.60E-14	1.59E+01	7.74E-08	3.41E+07	1.61E-09	7.09E+05	2.01E-08	8.85E+06	1.98E-14	8.72E+00	1.56E-09	6.87E+05	1.06E-08	4.65E+06
Pu-238	2.29E+03	1.04E-05	8.81E+10	4.40E-10	3.73E+06	3.20E-04	2.71E+12	5.80E-05	4.91E+11	7.25E-04	6.14E+12	3.86E-10	3.27E+06	2.74E-05	2.32E+11	7.79E-05	6.60E+11
Pu-239	1.77E+02	1.20E-05	7.86E+09	3.99E-10	2.61E+05	3.23E-04	2.12E+11	6.57E-05	4.30E+10	8.21E-04	5.38E+11	3.75E-10	2.46E+05	3.02E-05	1.98E+10	8.33E-05	5.46E+10
Pu-240	3.18E+02	1.20E-05	1.41E+10	4.33E-10	5.09E+05	3.23E-04	3.80E+11	6.57E-05	7.73E+10	8.21E-04	9.66E+11	3.76E-10	4.42E+05	3.02E-05	3.55E+10	8.33E-05	9.81E+10
Pu-241	2.47E+04	2.76E-07	2.52E+10	2.14E-11	1.96E+06	3.18E-06	2.91E+11	1.43E-06	1.31E+11	1.78E-05	1.63E+12	9.15E-12	8.36E+05	6.02E-07	5.50E+10	1.34E-06	1.22E+11
Pu-242	1.64E+00	1.14E-05	6.92E+07	4.35E-10	2.64E+03	3.07E-04	1.86E+09	6.25E-05	3.79E+08	7.81E-04	4.74E+09	3.71E-10	2.25E+03	2.86E-05	1.74E+08	7.92E-05	4.81E+08
Ra-226	0.00E+00	1.02E-07	0.00E+00	1.02E-07	0.00E+00	1.61E-05	0.00E+00	6.64E-07	0.00E+00	7.59E-06	0.00E+00	1.02E-07	0.00E+00	1.07E-07	0.00E+00	2.32E-06	0.00E+00
Ra-228	0.00E+00	1.83E-07	0.00E+00	1.84E-07	0.00E+00	7.22E-06	0.00E+00	7.38E-07	0.00E+00	6.51E-06	0.00E+00	1.83E-07	0.00E+00	1.87E-07	0.00E+00	1.29E-06	0.00E+00
Ru-106	1.23E-02	1.30E-09	5.92E+01	1.78E-09	8.10E+01	1.04E-06	4.73E+04	1.76E-09	8.01E+01	1.61E-09	7.33E+01	1.72E-09	7.83E+01	1.20E-08	5.46E+02	1.29E-07	5.88E+03
Sb-125	9.71E+00	3.60E-10	1.29E+04	4.16E-10	1.49E+04	2.17E-08	7.80E+05	5.35E-10	1.92E+04	9.78E-10	3.51E+04	3.24E-10	1.16E+04	1.45E-09	5.21E+04	3.30E-09	1.19E+05
Se-79	4.57E-02	5.98E-10	1.01E+02	5.98E-10	1.01E+02	9.81E-09	1.66E+03	5.98E-10	1.01E+02	5.98E-10	1.01E+02	5.98E-10	1.01E+02	3.77E-09	6.37E+02	2.66E-09	4.49E+02
Sm-147	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.26E-06	0.00E+00	2.75E-05	0.00E+00	3.44E-04	0.00E+00	0.00E+00	0.00E+00	1.89E-05	0.00E+00	2.02E-05	0.00E+00
Sm-151	2.11E+02	4.03E-14	3.15E+01	1.49E-13	1.16E+02	3.26E-09	2.55E+06	1.10E-08	8.59E+06	1.38E-07	1.08E+08	1.32E-14	1.03E+01	7.51E-09	5.86E+06	8.10E-09	6.33E+06
Sn-126	3.85E-01	4.95E-09	7.05E+03	5.39E-09	7.68E+03	1.51E-07	2.15E+05	1.69E-08	2.41E+04	3.33E-08	4.74E+04	4.90E-09	6.98E+03	1.20E-08	1.71E+04	2.69E-08	3.84E+04
Sr-90	2.72E+04	2.64E-09	2.66E+08	2.64E-09	2.66E+08	3.73E-09	3.75E+08	3.36E-07	3.38E+10	7.27E-07	7.32E+10	2.64E-09	2.66E+08	3.36E-09	3.38E+08	6.47E-08	6.51E+09
Tc-99	8.99E+00	3.99E-11	1.33E+03	3.99E-11	1.33E+03	1.67E-08	5.55E+05	3.99E-11	1.33E+03	3.99E-11	1.33E+03	1.07E-09	3.56E+04	6.26E-10	2.08E+04	2.25E-09	7.47E+04
Th-229	0.00E+00	1.18E-06	0.00E+00	1.18E-06	0.00E+00	1.99E-03	0.00E+00	4.60E-04	0.00E+00	5.73E-03	0.00E+00	1.18E-06	0.00E+00	3.02E-06	0.00E+00	4.67E-04	0.00E+00
Th-230	1.48E-04	1.72E-07	9.42E+01	1.72E-07	9.42E+01	3.00E-04	1.64E+05	6.99E-05	3.83E+04	8.71E-04	4.77E+05	1.72E-07	9.42E+01	4.48E-07	2.45E+02	7.07E-05	3.87E+04
Th-232	0.00E+00	5.98E-07	0.00E+00	6.14E-07	0.00E+00	9.40E-04	0.00E+00	4.01E-04	0.00E+00	4.99E-03	0.00E+00	5.99E-07	0.00E+00	1.51E-06	0.00E+00	3.11E-04	0.00E+00
U-232	2.05E-02	1.69E-08	1.28E+03	2.66E-08	2.02E+03	1.48E-03	1.12E+08	4.68E-07	3.55E+04	7.14E-06	5.42E+05	2.43E-08	1.84E+03	5.86E-07	4.44E+04	1.78E-04	1.35E+07
U-233	4.07E-05	2.69E-09	4.05E-01	2.73E-09	4.11E-01	3.04E-04	4.58E+04	7.39E-08	1.11E+01	1.16E-06	1.75E+02	2.70E-09	4.07E-01	1.08E-07	1.63E+01	3.66E-05	5.51E+03
U-234	6.77E-01	2.65E-09	6.64E+03	2.68E-09	6.71E+03	2.98E-04	7.46E+08	7.22E-08	1.81E+05	1.13E-06	2.83E+06	2.65E-09	6.64E+03	1.06E-07	2.66E+05	3.58E-05	8.98E+07
U-235	7.36E-03	2.84E-09	7.73E+01	5.37E-09	1.46E+02	2.76E-04	7.52E+06	7.15E-08	1.95E+03	1.05E-06	2.86E+04	4.11E-09	1.12E+02	1.02E-07	2.78E+03	3.32E-05	9.04E+05
U-236	1.72E-01	2.51E-09	1.60E+03	2.54E-09	1.62E+03	2.82E-04	1.79E+08	6.83E-08	4.35E+04	1.07E-06	6.81E+05	2.51E-09	1.60E+03	1.19E-09	7.57E+02	3.39E-05	2.16E+07
U-238	1.48E-01	2.42E-09	1.33E+03	2.91E-09	1.59E+03	2.66E-04	1.46E+08	6.88E-08	3.77E+04	1.01E-06	5.53E+05	2.73E-09	1.49E+03	9.61E-08	5.26E+04	3.20E-05	1.75E+07
Zr-93	8.94E-01	5.58E-12	1.85E+01	1.20E-11	3.97E+01	3.30E-09	1.09E+04	4.49E-08	1.49E+05	5.54E-07	1.83E+06	4.45E-12	1.47E+01	1.54E-10	5.09E+02	2.25E-08	7.43E+04

Inhalation Dose
Maximum PWR Assembly
Inhalation Dose Conversion Factors from Federal Guidance Report #11 (Eckerman et al. 1988 Table 2.1)

Nuclide	Curies/FA	Gonad DCF (Sv/Bq)	Rem/FA	Breast DCF (Sv/Bq)	Rem/FA	Lung DCF (Sv/Bq)	Rem/FA	R Marrow DCF (Sv/Bq)	Rem/FA	Bone Surface DCF (Sv/Bq)	Rem/FA	Thyroid DCF (Sv/Bq)	Rem/FA	Remainder DCF (Sv/Bq)	Rem/FA	Whole Body DCF (Sv/Bq)	Rem/FA
Ac-227	0.00E+00	3.56E-05	0.00E+00	1.06E-08	0.00E+00	1.54E-03	0.00E+00	2.33E-04	0.00E+00	2.91E-03	0.00E+00	6.47E-09	0.00E+00	1.34E-04	0.00E+00	3.49E-04	0.00E+00
Am-241	8.71E+02	3.25E-05	1.05E+11	2.67E-09	8.60E+06	1.84E-05	5.93E+10	1.74E-04	5.61E+11	2.17E-03	6.99E+12	1.60E-09	5.16E+06	7.82E-05	2.52E+11	1.20E-04	3.86E+11
Am-242m	1.02E+01	3.21E-05	1.21E+09	1.38E-09	5.21E+04	4.20E-06	1.59E+08	1.69E-04	6.38E+09	2.12E-03	8.00E+10	5.64E-10	2.13E+04	7.48E-05	2.82E+09	1.15E-04	4.33E+09
Am-243	5.22E+01	3.26E-05	6.30E+09	1.52E-08	2.94E+06	1.78E-05	3.44E+09	1.73E-04	3.34E+10	2.17E-03	4.19E+11	8.29E-09	1.60E+06	7.74E-05	1.49E+10	1.19E-04	2.31E+10
C-14	4.89E-01	6.36E-12	1.15E+01	6.36E-12	1.15E+01	6.36E-12	1.15E+01	6.36E-12	1.15E+01	6.36E-12	1.15E+01	6.36E-12	1.15E+01	6.36E-12	1.15E+01	6.36E-12	1.15E+01
Cd-113m	3.82E+01	4.72E-09	6.67E+05	4.72E-09	6.67E+05	4.09E-07	5.78E+07	4.72E-09	6.67E+05	4.72E-09	6.67E+05	4.72E-09	6.67E+05	1.86E-07	2.63E+07	1.08E-07	1.52E+07
Cl-36	9.69E-03	5.04E-10	1.81E+01	5.04E-10	1.81E+01	4.56E-08	1.63E+03	5.04E-10	1.81E+01	5.04E-10	1.81E+01	5.04E-10	1.81E+01	5.36E-10	1.92E+01	5.93E-09	2.12E+02
Cm-242	3.43E+01	5.70E-07	7.23E+07	9.44E-10	1.20E+05	1.55E-05	1.97E+09	3.90E-06	4.95E+08	4.87E-05	6.18E+09	9.41E-10	1.19E+05	2.45E-06	3.11E+08	4.67E-06	5.92E+08
Cm-243	3.83E+01	2.07E-05	2.93E+09	6.29E-09	8.91E+05	1.94E-05	2.75E+09	1.18E-04	1.67E+10	1.47E-03	2.08E+11	3.83E-09	5.43E+05	5.76E-05	8.16E+09	8.30E-05	1.18E+10
Cm-244	1.12E+04	1.59E-05	6.59E+11	1.04E-09	4.31E+07	1.93E-05	8.00E+11	9.38E-05	3.89E+12	1.17E-03	4.85E+13	1.01E-09	4.19E+07	4.78E-05	1.98E+12	6.70E-05	2.78E+12
Cm-245	1.41E+00	3.37E-05	1.76E+08	6.69E-09	3.49E+04	1.80E-05	9.39E+07	1.79E-04	9.34E+08	2.24E-03	1.17E+10	3.68E-09	1.92E+04	7.96E-05	4.15E+08	1.23E-04	6.42E+08
Cm-246	8.38E-01	3.34E-05	1.04E+08	4.00E-09	1.24E+04	1.82E-05	5.64E+07	1.78E-04	5.52E+08	2.22E-03	6.88E+09	2.26E-09	7.01E+03	7.94E-05	2.46E+08	1.22E-04	3.79E+08
Co-60	5.66E+03	4.76E-09	9.97E+07	1.84E-08	3.85E+08	3.45E-07	7.22E+09	1.72E-08	3.60E+08	1.35E-08	2.83E+08	1.62E-08	3.39E+08	3.60E-08	7.54E+08	5.91E-08	1.24E+09
Cs-134	3.72E+04	1.30E-08	1.79E+09	1.08E-08	1.49E+09	1.18E-08	1.62E+09	1.18E-08	1.62E+09	1.10E-08	1.51E+09	1.11E-08	1.53E+09	1.39E-08	1.91E+09	1.25E-08	1.73E+09
Cs-135	5.99E-01	1.20E-09	2.66E+03	1.20E-09	2.66E+03	1.41E-09	3.12E+03	1.20E-09	2.66E+03	1.20E-09	2.66E+03	1.20E-09	2.66E+03	1.20E-09	2.66E+03	1.23E-09	2.72E+03
Cs-137	9.87E+04	8.76E-09	3.20E+09	7.84E-09	2.86E+09	8.82E-09	3.22E+09	8.30E-09	3.03E+09	7.94E-09	2.90E+09	7.93E-09	2.90E+09	9.12E-09	3.33E+09	8.63E-09	3.15E+09
Eu-154	5.77E+03	1.17E-08	2.50E+08	1.55E-08	3.31E+08	7.92E-08	1.69E+09	1.06E-07	2.26E+09	5.23E-07	1.12E+10	7.14E-09	1.52E+08	1.13E-07	2.41E+09	7.73E-08	1.65E+09
Eu-155	1.68E+03	3.56E-10	2.21E+06	6.14E-10	3.82E+06	1.19E-08	7.40E+07	1.43E-08	8.89E+07	1.52E-07	9.45E+08	2.40E-10	1.49E+06	1.11E-08	6.90E+07	1.12E-08	6.98E+07
Fe-55	6.84E+02	1.79E-10	4.53E+05	1.74E-10	4.40E+05	1.06E-09	2.68E+06	1.76E-10	4.45E+05	1.75E-10	4.43E+05	1.85E-10	4.68E+05	4.37E-10	1.11E+06	3.61E-10	9.14E+05
H-3	4.72E+02	1.73E-11	3.02E+04	1.73E-11	3.02E+04	1.73E-11	3.02E+04	1.73E-11	3.02E+04	1.73E-11	3.02E+04	1.73E-11	3.02E+04	1.73E-11	3.02E+04	1.73E-11	3.02E+04
I-129	3.38E-02	8.69E-11	1.09E+01	2.09E-10	2.61E+01	3.14E-10	3.93E+01	1.40E-10	1.75E+01	1.38E-10	1.73E+01	1.56E-06	1.95E+05	1.18E-10	1.48E+01	4.69E-08	5.87E+03
Kr-85	5.63E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nb-93m	4.54E+01	1.55E-10	2.60E+04	4.36E-11	7.32E+03	6.45E-08	1.08E+07	1.14E-10	1.91E+04	2.84E-10	4.77E+04	1.14E-11	1.91E+03	3.04E-10	5.11E+04	7.90E-09	1.33E+06
Nb-94	1.27E+00	4.42E-09	2.08E+04	2.24E-08	1.05E+05	7.48E-07	3.51E+06	2.26E-08	1.06E+05	1.97E-08	9.26E+04	2.22E-08	1.04E+05	4.45E-08	2.09E+05	1.12E-07	5.24E+05
Ni-59	2.78E+00	1.09E-10	1.12E+03	1.05E-10	1.08E+03	1.20E-09	1.23E+04	1.06E-10	1.09E+03	1.05E-10	1.08E+03	1.14E-10	1.17E+03	1.40E-10	1.44E+03	2.48E-10	2.55E+03
Ni-63	4.16E+02	2.47E-10	3.80E+05	2.47E-10	3.80E+05	3.07E-09	4.73E+06	2.47E-10	3.80E+05	2.47E-10	3.80E+05	2.47E-10	3.80E+05	3.67E-10	5.65E+05	6.22E-10	9.57E+05
Np-237	3.85E-01	2.96E-05	4.22E+07	1.69E-08	2.41E+04	1.61E-05	2.29E+07	2.62E-04	3.73E+08	3.27E-03	4.66E+09	1.34E-08	1.91E+04	2.34E-05	3.33E+07	1.46E-04	2.08E+08
Pa-231	4.25E-05	3.06E-09	4.81E-01	5.65E-09	8.88E-01	7.47E-04	1.17E+05	2.88E-04	4.53E+04	3.60E-03	5.66E+05	4.45E-09	7.00E-01	2.12E-07	3.33E+01	2.32E-04	3.65E+04
Pb-210	0.00E+00	3.18E-07	0.00E+00	3.18E-07	0.00E+00	3.18E-07	0.00E+00	3.75E-06	0.00E+00	5.47E-05	0.00E+00	3.18E-07	0.00E+00	4.69E-06	0.00E+00	3.67E-06	0.00E+00
Pd-107	1.45E-01	1.05E-13	5.63E-02	1.05E-13	5.63E-02	2.85E-08	1.53E+04	5.68E-13	3.05E-01	1.51E-12	8.10E-01	1.05E-13	5.63E-02	9.71E-11	5.21E+01	3.45E-09	1.85E+03
Pm-147	2.34E+04	8.25E-15	7.14E+02	3.60E-14	3.12E+03	7.74E-08	6.70E+09	1.61E-09	1.39E+08	2.01E-08	1.74E+09	1.98E-14	1.71E+03	1.56E-09	1.35E+08	1.06E-08	9.14E+08
Pu-238	6.16E+03	1.04E-05	2.37E+11	4.40E-10	1.00E+07	3.20E-04	7.29E+12	5.80E-05	1.32E+12	7.25E-04	1.65E+13	3.86E-10	8.80E+06	2.74E-05	6.25E+11	7.79E-05	1.78E+12
Pu-239	1.85E+02	1.20E-05	8.21E+09	3.99E-10	2.73E+05	3.23E-04	2.21E+11	6.57E-05	4.50E+10	8.21E-04	5.62E+11	3.75E-10	2.57E+05	3.02E-05	2.07E+10	8.33E-05	5.70E+10
Pu-240	3.90E+02	1.20E-05	1.73E+10	4.33E-10	6.25E+05	3.23E-04	4.66E+11	6.57E-05	9.48E+10	8.21E-04	1.18E+12	3.76E-10	5.43E+05	3.02E-05	4.36E+10	8.33E-05	1.20E+11
Pu-241	7.91E+04	2.76E-07	8.08E+10	2.14E-11	6.26E+06	3.18E-06	9.31E+11	1.43E-06	4.19E+11	1.78E-05	5.21E+12	9.15E-12	2.68E+06	6.02E-07	1.76E+11	1.34E-06	3.91E+11
Pu-242	3.01E+00	1.14E-05	1.27E+08	4.35E-10	4.84E+03	3.07E-04	3.42E+09	6.25E-05	6.96E+08	7.81E-04	8.70E+09	3.71E-10	4.13E+03	2.86E-05	3.19E+08	7.92E-05	8.82E+08
Ra-226	0.00E+00	1.02E-07	0.00E+00	1.02E-07	0.00E+00	1.61E-05	0.00E+00	6.64E-07	0.00E+00	7.59E-06	0.00E+00	1.02E-07	0.00E+00	1.07E-07	0.00E+00	2.32E-06	0.00E+00
Ra-228	0.00E+00	1.83E-07	0.00E+00	1.84E-07	0.00E+00	7.22E-06	0.00E+00	7.38E-07	0.00E+00	6.51E-06	0.00E+00	1.83E-07	0.00E+00	1.87E-07	0.00E+00	1.29E-06	0.00E+00
Ru-106	1.27E+04	1.30E-09	6.11E+07	1.78E-09	8.36E+07	1.04E-06	4.89E+10	1.76E-09	8.27E+07	1.61E-09	7.57E+07	1.72E-09	8.08E+07	1.20E-08	5.64E+08	1.29E-07	6.08E+09
Sb-125	2.05E+03	3.60E-10	2.73E+06	4.16E-10	3.16E+06	2.17E-08	1.65E+08	5.35E-10	4.06E+06	9.78E-10	7.42E+06	3.24E-10	2.46E+06	1.45E-09	1.10E+07	3.30E-09	2.50E+07
Se-79	6.95E-02	5.98E-10	1.54E+02	5.98E-10	1.54E+02	9.81E-09	2.52E+03	5.98E-10	1.54E+02	5.98E-10	1.54E+02	5.98E-10	1.54E+02	3.77E-09	9.69E+02	2.66E-09	6.83E+02
Sm-147	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.26E-06	0.00E+00	2.75E-05	0.00E+00	3.44E-04	0.00E+00	0.00E+00	0.00E+00	1.89E-05	0.00E+00	2.02E-05	0.00E+00
Sm-151	3.13E+02	4.03E-14	4.67E+01	1.49E-13	1.73E+02	3.26E-09	3.78E+06	1.10E-08	1.27E+07	1.38E-07	1.60E+08	1.32E-14	1.53E+01	7.51E-09	8.70E+06	8.10E-09	9.39E+06
Sn-126	6.28E-01	4.95E-09	1.15E+04	5.39E-09	1.25E+04	1.51E-07	3.51E+05	1.69E-08	3.93E+04	3.33E-08	7.74E+04	4.90E-09	1.14E+04	1.20E-08	2.79E+04	2.69E-08	6.26E+04
Sr-90	6.30E+04	2.64E-09	6.15E+08	2.64E-09	6.15E+08	3.73E-09	8.69E+08	3.36E-07	7.83E+10	7.27E-07	1.69E+11	2.64E-09	6.15E+08	3.36E-09	7.83E+08	6.47E-08	1.51E+10
Tc-99	1.28E+01	3.99E-11	1.89E+03	3.99E-11	1.89E+03	1.67E-08	7.91E+05	3.99E-11	1.89E+03	3.99E-11	1.89E+03	1.07E-09	5.07E+04	6.26E-10	2.96E+04	2.25E-09	1.06E+05
Th-229	0.00E+00	1.18E-06	0.00E+00	1.18E-06	0.00E+00	1.99E-03	0.00E+00	4.60E-04	0.00E+00	5.73E-03	0.00E+00	1.18E-06	0.00E+00	3.02E-06	0.00E+00	4.67E-04	0.00E+00
Th-230	3.56E-05	1.72E-07	2.27E+01	1.72E-07	2.27E+01	3.00E-04	3.95E+04	6.99E-05	9.21E+03	8.71E-04	1.15E+05	1.72E-07	2.27E+01	4.48E-07	5.90E+01	7.07E-05	9.32E+03
Th-232	0.00E+00	5.98E-07	0.00E+00	6.14E-07	0.00E+00	9.40E-04	0.00E+00	4.01E-04	0.00E+00	4.99E-03	0.00E+00	5.99E-07	0.00E+00	1.51E-06	0.00E+00	3.11E-04	0.00E+00
U-232	5.31E-02	1.69E-08	3.32E+03	2.66E-08	5.23E+03	1.48E-03	2.91E+08	4.68E-07	9.19E+04	7.14E-06	1.40E+06	2.43E-08	4.77E+03	5.86E-07	1.15E+05	1.78E-04	3.50E+07
U-233	2.42E-05	2.69E-09	2.41E-01	2.73E-09	2.44E-01	3.04E-04	2.72E+04	7.39E-08	6.62E+00	1.16E-06	1.04E+02	2.70E-09	2.42E-01	1.08E-07	9.67E+00	3.66E-05	3.27E+03
U-234	5.46E-01	2.65E-09	5.35E+03	2.68E-09	5.41E+03	2.98E-04	6.02E+08	7.22E-08	1.46E+05	1.13E-06	2.28E+06	2.65E-09	5.35E+03	1.06E-07	2.14E+05	3.58E-05	7.24E+07
U-235	4.15E-03	2.84E-09	4.36E+01	5.37E-09	8.25E+01	2.76E-04	4.24E+06	7.15E-08	1.10E+03	1.05E-06	1.61E+04	4.11E-09	6.31E+01	1.02E-07	1.57E+03	3.32E-05	5.10E+05
U-236	2.24E-01	2.51E-09	2.08E+03	2.54E-09	2.11E+03	2.82E-04	2.34E+08	6.83E-08	5.66E+04	1.07E-06	8.87E+05	2.51E-09	2.08E+03	1.19E-09	9.86E+02	3.39E-05	2.81E+07
U-238	1.43E-01	2.42E-09	1.28E+03	2.91E-09	1.54E+03	2.66E-04	1.41E+08	6.88E-08	3.64E+04	1.01E-06	5.34E+05	2.73E-09	1.44E+03	9.61E-08	5.08E+04	3.20E-05	1.69E+07
Zr-93	1.33E+00	5.58E-12	2.75E+01	1.20E-11	5.91E+01	3.30E-09	1.62E+04	4.49E-08	2.21E+05	5.54E-07	2.73E+06	4.45E-12	2.19E+01	1.54E-10	7.58E+02	2.25E-08	1.10E+05

Inhalation Dose
Average BWR Assembly
Inhalation Dose Conversion Factors from Federal Guidance Report #11 (Eckerman et al. 1988 Table 2.1)

Nuclide	Curies/FA	Gonad DCF (Sv/Bq)	Rem/FA	Breast DCF (Sv/Bq)	Rem/FA	Lung DCF (Sv/Bq)	Rem/FA	R Marrow DCF (Sv/Bq)	Rem/FA	Bone Surface DCF (Sv/Bq)	Rem/FA	Thyroid DCF (Sv/Bq)	Rem/FA	Remainder DCF (Sv/Bq)	Rem/FA	Whole Body DCF (Sv/Bq)	Rem/FA
Ac-227	0.00E+00	3.56E-05	0.00E+00	1.06E-08	0.00E+00	1.54E-03	0.00E+00	2.33E-04	0.00E+00	2.91E-03	0.00E+00	6.47E-09	0.00E+00	1.34E-04	0.00E+00	3.49E-04	0.00E+00
Am-241	5.58E+02	3.25E-05	6.71E+10	2.67E-09	5.51E+06	1.84E-05	3.80E+10	1.74E-04	3.59E+11	2.17E-03	4.48E+12	1.60E-09	3.30E+06	7.82E-05	1.61E+11	1.20E-04	2.47E+11
Am-242m	2.17E+00	3.21E-05	2.58E+08	1.38E-09	1.11E+04	4.20E-06	3.37E+07	1.69E-04	1.36E+09	2.12E-03	1.70E+10	5.64E-10	4.53E+03	7.48E-05	6.01E+08	1.15E-04	9.22E+08
Am-243	5.35E+00	3.26E-05	6.45E+08	1.52E-08	3.01E+05	1.78E-05	3.52E+08	1.73E-04	3.42E+09	2.17E-03	4.30E+10	8.29E-09	1.64E+05	7.74E-05	1.53E+09	1.19E-04	2.36E+09
C-14	1.75E-01	6.36E-12	4.12E+00	6.36E-12	4.12E+00	6.36E-12	4.12E+00	6.36E-12	4.12E+00	6.36E-12	4.12E+00	6.36E-12	4.12E+00	6.36E-12	4.12E+00	6.36E-12	4.12E+00
Cd-113m	2.26E+00	4.72E-09	3.95E+04	4.72E-09	3.95E+04	4.09E-07	3.42E+06	4.72E-09	3.95E+04	4.72E-09	3.95E+04	4.72E-09	3.95E+04	1.86E-07	1.56E+06	1.08E-07	9.00E+05
Cl-36	2.93E-03	5.04E-10	5.46E+00	5.04E-10	5.46E+00	4.56E-08	4.94E+02	5.04E-10	5.46E+00	5.04E-10	5.46E+00	5.04E-10	5.46E+00	5.36E-10	5.81E+00	5.93E-09	6.42E+01
Cm-242	1.79E+00	5.70E-07	3.78E+06	9.44E-10	6.25E+03	1.55E-05	1.03E+08	3.90E-06	2.58E+07	4.87E-05	3.23E+08	9.41E-10	6.23E+03	2.45E-06	1.62E+07	4.67E-06	3.09E+07
Cm-243	2.48E+00	2.07E-05	1.90E+08	6.29E-09	5.77E+04	1.94E-05	1.78E+08	1.18E-04	1.08E+09	1.47E-03	1.35E+10	3.83E-09	3.51E+04	5.76E-05	5.29E+08	8.30E-05	7.62E+08
Cm-244	2.56E+02	1.59E-05	1.51E+10	1.04E-09	9.85E+05	1.93E-05	1.83E+10	9.38E-05	8.88E+10	1.17E-03	1.11E+12	1.01E-09	9.57E+05	4.78E-05	4.53E+10	6.70E-05	6.35E+10
Cm-245	4.04E-02	3.37E-05	5.04E+06	6.69E-09	1.00E+03	1.80E-05	2.69E+06	1.79E-04	2.68E+07	2.24E-03	3.35E+08	3.68E-09	5.50E+02	7.96E-05	1.19E+07	1.23E-04	1.84E+07
Cm-246	1.45E-02	3.34E-05	1.79E+06	4.00E-09	2.15E+02	1.82E-05	9.76E+05	1.78E-04	9.55E+06	2.22E-03	1.19E+08	2.26E-09	1.21E+02	7.94E-05	4.26E+06	1.22E-04	6.56E+06
Co-60	4.40E+01	4.76E-09	7.75E+05	1.84E-08	3.00E+06	3.45E-07	5.62E+07	1.72E-08	2.80E+06	1.35E-08	2.20E+06	1.62E-08	2.64E+06	3.60E-08	5.86E+06	5.91E-08	9.62E+06
Cs-134	6.32E+00	1.30E-08	3.04E+05	1.08E-08	2.53E+05	1.18E-08	2.76E+05	1.18E-08	2.76E+05	1.10E-08	2.57E+05	1.11E-08	2.60E+05	1.39E-08	3.25E+05	1.25E-08	2.93E+05
Cs-135	1.39E-01	1.20E-09	6.17E+02	1.20E-09	6.17E+02	1.41E-09	7.25E+02	1.20E-09	6.17E+02	1.20E-09	6.17E+02	1.20E-09	6.17E+02	1.20E-09	6.17E+02	1.23E-09	6.30E+02
Cs-137	1.39E+04	8.76E-09	4.51E+08	7.84E-09	4.03E+08	8.82E-09	4.54E+08	8.30E-09	4.27E+08	7.94E-09	4.08E+08	7.93E-09	4.08E+08	9.12E-09	4.69E+08	8.63E-09	4.44E+08
Eu-154	1.80E+02	1.17E-08	7.79E+06	1.55E-08	1.03E+07	7.92E-08	5.27E+07	1.06E-07	7.06E+07	5.23E-07	3.48E+08	7.14E-09	4.76E+06	1.13E-07	7.53E+07	7.73E-08	5.15E+07
Eu-155	1.64E+01	3.56E-10	2.16E+04	6.14E-10	3.73E+04	1.19E-08	7.22E+05	1.43E-08	8.68E+05	1.52E-07	9.22E+06	2.40E-10	1.46E+04	1.11E-08	6.74E+05	1.12E-08	6.81E+05
Fe-55	1.09E+00	1.79E-10	7.22E+02	1.74E-10	7.02E+02	1.06E-09	4.27E+03	1.76E-10	7.10E+02	1.75E-10	7.06E+02	1.85E-10	7.46E+02	4.37E-10	1.76E+03	3.61E-10	1.46E+03
H-3	3.95E+01	1.73E-11	2.53E+03	1.73E-11	2.53E+03	1.73E-11	2.53E+03	1.73E-11	2.53E+03	1.73E-11	2.53E+03	1.73E-11	2.53E+03	1.73E-11	2.53E+03	1.73E-11	2.53E+03
I-129	7.43E-03	8.69E-11	2.39E+00	2.09E-10	5.75E+00	3.14E-10	8.63E+00	1.40E-10	3.85E+00	1.38E-10	3.79E+00	1.56E-06	4.29E+04	1.18E-10	3.24E+00	4.69E-08	1.29E+03
Kr-85	3.81E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nb-93m	4.74E-01	1.55E-10	2.72E+02	4.36E-11	7.65E+01	6.45E-08	1.13E+05	1.14E-10	2.00E+02	2.84E-10	4.98E+02	1.14E-11	2.00E+01	3.04E-10	5.33E+02	7.90E-09	1.39E+04
Nb-94	1.87E-02	4.42E-09	3.06E+02	2.24E-08	1.55E+03	7.48E-07	5.18E+04	2.26E-08	1.56E+03	1.97E-08	1.36E+03	2.22E-08	1.54E+03	4.45E-08	3.08E+03	1.12E-07	7.72E+03
Ni-59	5.03E-01	1.09E-10	2.03E+02	1.05E-10	1.95E+02	1.20E-09	2.23E+03	1.06E-10	1.97E+02	1.05E-10	1.95E+02	1.14E-10	2.12E+02	1.40E-10	2.61E+02	2.48E-10	4.62E+02
Ni-63	5.87E+01	2.47E-10	5.36E+04	2.47E-10	5.36E+04	3.07E-09	6.67E+05	2.47E-10	5.36E+04	2.47E-10	5.36E+04	2.47E-10	5.36E+04	3.67E-10	7.97E+04	6.22E-10	1.35E+05
Np-237	6.89E-02	2.96E-05	7.55E+06	1.69E-08	4.31E+03	1.61E-05	4.10E+06	2.62E-04	6.68E+07	3.27E-03	8.34E+08	1.34E-08	3.42E+03	2.34E-05	5.97E+06	1.46E-04	3.72E+07
Pa-231	1.39E-05	3.06E-09	1.57E-01	5.65E-09	2.91E-01	7.47E-04	3.84E+04	2.88E-04	1.48E+04	3.60E-03	1.85E+05	4.45E-09	2.29E-01	2.12E-07	1.09E+01	2.32E-04	1.19E+04
Pb-210	0.00E+00	3.18E-07	0.00E+00	3.18E-07	0.00E+00	3.18E-07	0.00E+00	3.75E-06	0.00E+00	5.47E-05	0.00E+00	3.18E-07	0.00E+00	4.69E-06	0.00E+00	3.67E-06	0.00E+00
Pd-107	2.65E-02	1.05E-13	1.03E-02	1.05E-13	1.03E-02	2.85E-08	2.79E+03	5.68E-13	5.57E-02	1.51E-12	1.48E-01	1.05E-13	1.03E-02	9.71E-11	9.52E+00	3.45E-09	3.38E+02
Pm-147	3.98E+01	8.25E-15	1.21E+00	3.60E-14	5.30E+00	7.74E-08	1.14E+07	1.61E-09	2.37E+05	2.01E-08	2.96E+06	1.98E-14	2.92E+00	1.56E-09	2.30E+05	1.06E-08	1.55E+06
Pu-238	5.85E+02	1.04E-05	2.25E+10	4.40E-10	9.52E+05	3.20E-04	6.93E+11	5.80E-05	1.26E+11	7.25E-04	1.57E+12	3.86E-10	8.35E+05	2.74E-05	5.93E+10	7.79E-05	1.69E+11
Pu-239	5.35E+01	1.20E-05	2.38E+09	3.99E-10	7.90E+04	3.23E-04	6.39E+10	6.57E-05	1.30E+10	8.21E-04	1.63E+11	3.75E-10	7.42E+04	3.02E-05	5.98E+09	8.33E-05	1.65E+10
Pu-240	1.14E+02	1.20E-05	5.06E+09	4.33E-10	1.83E+05	3.23E-04	1.36E+11	6.57E-05	2.77E+10	8.21E-04	3.46E+11	3.76E-10	1.59E+05	3.02E-05	1.27E+10	8.33E-05	3.52E+10
Pu-241	6.78E+03	2.76E-07	6.92E+09	2.14E-11	5.37E+05	3.18E-06	7.98E+10	1.43E-06	3.59E+10	1.78E-05	4.47E+11	9.15E-12	2.30E+05	6.02E-07	1.51E+10	1.34E-06	3.35E+10
Pu-242	5.09E-01	1.14E-05	2.15E+07	4.35E-10	8.19E+02	3.07E-04	5.78E+08	6.25E-05	1.18E+08	7.81E-04	1.47E+09	3.71E-10	6.99E+02	2.86E-05	5.39E+07	7.92E-05	1.49E+08
Ra-226	0.00E+00	1.02E-07	0.00E+00	1.02E-07	0.00E+00	1.61E-05	0.00E+00	6.64E-07	0.00E+00	7.59E-06	0.00E+00	1.02E-07	0.00E+00	1.07E-07	0.00E+00	2.32E-06	0.00E+00
Ra-228	0.00E+00	1.83E-07	0.00E+00	1.84E-07	0.00E+00	7.22E-06	0.00E+00	7.38E-07	0.00E+00	6.51E-06	0.00E+00	1.83E-07	0.00E+00	1.87E-07	0.00E+00	1.29E-06	0.00E+00
Ru-106	3.00E-03	1.30E-09	1.44E+01	1.78E-09	1.98E+01	1.04E-06	1.15E+04	1.76E-09	1.95E+01	1.61E-09	1.79E+01	1.72E-09	1.91E+01	1.20E-08	1.33E+02	1.29E-07	1.44E+03
Sb-125	2.89E+00	3.60E-10	3.85E+03	4.16E-10	4.45E+03	2.17E-08	2.32E+05	5.35E-10	5.72E+03	9.78E-10	1.05E+04	3.24E-10	3.46E+03	1.45E-09	1.55E+04	3.30E-09	3.53E+04
Se-79	1.59E-02	5.98E-10	3.52E+01	5.98E-10	3.52E+01	9.81E-09	5.77E+02	5.98E-10	3.52E+01	5.98E-10	3.52E+01	5.98E-10	3.52E+01	3.77E-09	2.22E+02	2.66E-09	1.56E+02
Sm-147	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.26E-06	0.00E+00	2.75E-05	0.00E+00	3.44E-04	0.00E+00	0.00E+00	0.00E+00	1.89E-05	0.00E+00	2.02E-05	0.00E+00
Sm-151	5.39E+01	4.03E-14	8.04E+00	1.49E-13	2.97E+01	3.26E-09	6.50E+05	1.10E-08	2.19E+06	1.38E-07	2.75E+07	1.32E-14	2.63E+00	7.51E-09	1.50E+06	8.10E-09	1.62E+06
Sn-126	1.27E-01	4.95E-09	2.33E+03	5.39E-09	2.53E+03	1.51E-07	7.10E+04	1.69E-08	7.94E+03	3.33E-08	1.56E+04	4.90E-09	2.30E+03	1.20E-08	5.64E+03	2.69E-08	1.27E+04
Sr-90	9.54E+03	2.64E-09	9.32E+07	2.64E-09	9.32E+07	3.73E-09	1.32E+08	3.36E-07	1.19E+10	7.27E-07	2.57E+10	2.64E-09	9.32E+07	3.36E-09	1.19E+08	6.47E-08	2.28E+09
Tc-99	3.20E+00	3.99E-11	4.72E+02	3.99E-11	4.72E+02	1.67E-08	1.98E+05	3.99E-11	4.72E+02	3.99E-11	4.72E+02	1.07E-09	1.27E+04	6.26E-10	7.41E+03	2.25E-09	2.66E+04
Th-229	0.00E+00	1.18E-06	0.00E+00	1.18E-06	0.00E+00	1.99E-03	0.00E+00	4.60E-04	0.00E+00	5.73E-03	0.00E+00	1.18E-06	0.00E+00	3.02E-06	0.00E+00	4.67E-04	0.00E+00
Th-230	6.09E-05	1.72E-07	3.88E+01	1.72E-07	3.88E+01	3.00E-04	6.76E+04	6.99E-05	1.58E+04	8.71E-04	1.96E+05	1.72E-07	3.88E+01	4.48E-07	1.01E+02	7.07E-05	1.59E+04
Th-232	0.00E+00	5.98E-07	0.00E+00	6.14E-07	0.00E+00	9.40E-04	0.00E+00	4.01E-04	0.00E+00	4.99E-03	0.00E+00	5.99E-07	0.00E+00	1.51E-06	0.00E+00	3.11E-04	0.00E+00
U-232	4.64E-03	1.69E-08	2.90E+02	2.66E-08	4.57E+02	1.48E-03	2.54E+07	4.68E-07	8.03E+03	7.14E-06	1.23E+05	2.43E-08	4.17E+02	5.86E-07	1.01E+04	1.78E-04	3.06E+06
U-233	1.14E-05	2.69E-09	1.13E-01	2.73E-09	1.15E-01	3.04E-04	1.28E+04	7.39E-08	3.12E+00	1.16E-06	4.89E+01	2.70E-09	1.14E-01	1.08E-07	4.56E+00	3.66E-05	1.54E+03
U-234	2.49E-01	2.65E-09	2.44E+03	2.68E-09	2.47E+03	2.98E-04	2.75E+08	7.22E-08	6.65E+04	1.13E-06	1.04E+06	2.65E-09	2.44E+03	1.06E-07	9.77E+04	3.58E-05	3.30E+07
U-235	2.62E-03	2.84E-09	2.75E+01	5.37E-09	5.21E+01	2.76E-04	2.68E+06	7.15E-08	6.93E+02	1.05E-06	1.02E+04	4.11E-09	3.98E+01	1.02E-07	9.89E+02	3.32E-05	3.22E+05
U-236	6.26E-02	2.51E-09	5.81E+02	2.54E-09	5.88E+02	2.82E-04	6.53E+07	6.83E-08	1.58E+04	1.07E-06	2.48E+05	2.51E-09	5.81E+02	1.19E-09	2.76E+02	3.39E-05	7.85E+06
U-238	6.32E-02	2.42E-09	5.66E+02	2.91E-09	6.80E+02	2.66E-04	6.22E+07	6.88E-08	1.61E+04	1.01E-06	2.36E+05	2.73E-09	6.38E+02	9.61E-08	2.25E+04	3.20E-05	7.48E+06
Zr-93	3.38E-01	5.58E-12	6.98E+00	1.20E-11	1.50E+01	3.30E-09	4.13E+03	4.49E-08	5.62E+04	5.54E-07	6.93E+05	4.45E-12	5.57E+00	1.54E-10	1.93E+02	2.25E-08	2.81E+04

Inhalation Dose
Maximum BWR Assembly
Inhalation Dose Conversion Factors from Federal Guidance Report #11 (Eckerman et al. 1988 Table 2.1)

		Gonad		Breast		Lung		R Marrow		Bone Surface		Thyroid		Remainder		Whole Body	
		DCF		DCF		DCF		DCF		DCF		DCF		DCF		DCF	
Nuclide	Curies/FA	(Sv/Bq)	Rem/FA	(Sv/Bq)	Rem/FA	(Sv/Bq)	Rem/FA	(Sv/Bq)	Rem/FA	(Sv/Bq)	Rem/FA	(Sv/Bq)	Rem/FA	(Sv/Bq)	Rem/FA	(Sv/Bq)	Rem/FA	(Sv/Bq)	Rem/FA
Ac-227	0.00E+00	3.56E-05	0.00E+00	1.06E-08	0.00E+00	1.54E-03	0.00E+00	2.33E-04	0.00E+00	2.91E-03	0.00E+00	6.47E-09	0.00E+00	1.34E-04	0.00E+00	3.49E-04	0.00E+00
Am-241	2.66E+02	3.25E-05	3.20E+10	2.67E-09	2.63E+06	1.84E-05	1.81E+10	1.74E-04	1.71E+11	2.17E-03	2.14E+12	1.60E-09	1.57E+06	7.82E-05	7.70E+10	1.20E-04	1.18E+11
Am-242m	3.40E+00	3.21E-05	4.04E+08	1.38E-09	1.74E+04	4.20E-06	5.28E+07	1.69E-04	2.13E+09	2.12E-03	2.67E+10	5.64E-10	7.10E+03	7.48E-05	9.41E+08	1.15E-04	1.44E+09
Am-243	1.93E+01	3.26E-05	2.33E+09	1.52E-08	1.09E+06	1.78E-05	1.27E+09	1.73E-04	1.24E+10	2.17E-03	1.55E+11	8.29E-09	5.92E+05	7.74E-05	5.53E+09	1.19E-04	8.52E+09
C-14	3.16E-01	6.36E-12	7.44E+00	6.36E-12	7.44E+00	6.36E-12	7.44E+00	6.36E-12	7.44E+00	6.36E-12	7.44E+00	6.36E-12	7.44E+00	6.36E-12	7.44E+00	6.36E-12	7.44E+00
Cd-113m	1.39E+01	4.72E-09	2.43E+05	4.72E-09	2.43E+05	4.09E-07	2.10E+07	4.72E-09	2.43E+05	4.72E-09	2.43E+05	4.72E-09	2.43E+05	1.86E-07	9.57E+06	1.08E-07	5.53E+06
Cl-36	4.99E-03	5.04E-10	9.31E+00	5.04E-10	9.31E+00	4.56E-08	8.42E+02	5.04E-10	9.31E+00	5.04E-10	9.31E+00	5.04E-10	9.31E+00	5.36E-10	9.90E+00	5.93E-09	1.09E+02
Cm-242	1.13E+01	5.70E-07	2.38E+07	9.44E-10	3.95E+04	1.55E-05	6.48E+08	3.90E-06	1.63E+08	4.87E-05	2.04E+09	9.41E-10	3.93E+04	2.45E-06	1.02E+08	4.67E-06	1.95E+08
Cm-243	1.12E+01	2.07E-05	8.58E+08	6.29E-09	2.61E+05	1.94E-05	8.04E+08	1.18E-04	4.89E+09	1.47E-03	6.09E+10	3.83E-09	1.59E+05	5.76E-05	2.39E+09	8.30E-05	3.44E+09
Cm-244	3.95E+03	1.59E-05	2.32E+11	1.04E-09	1.52E+07	1.93E-05	2.82E+11	9.38E-05	1.37E+12	1.17E-03	1.71E+13	1.01E-09	1.48E+07	4.78E-05	6.99E+11	6.70E-05	9.79E+11
Cm-245	3.54E-01	3.37E-05	4.41E+07	6.69E-09	8.76E+03	1.80E-05	2.36E+07	1.79E-04	2.34E+08	2.24E-03	2.93E+09	3.68E-09	4.82E+03	7.96E-05	1.04E+08	1.23E-04	1.61E+08
Cm-246	2.97E-01	3.34E-05	3.67E+07	4.00E-09	4.40E+03	1.82E-05	2.00E+07	1.78E-04	1.96E+08	2.22E-03	2.44E+09	2.26E-09	2.48E+03	7.94E-05	8.73E+07	1.22E-04	1.34E+08
Co-60	8.56E+02	4.76E-09	1.51E+07	1.84E-08	5.83E+07	3.45E-07	1.09E+09	1.72E-08	5.45E+07	1.35E-08	4.28E+07	1.62E-08	5.13E+07	3.60E-08	1.14E+08	5.91E-08	1.87E+08
Cs-134	1.16E+04	1.30E-08	5.58E+08	1.08E-08	4.64E+08	1.18E-08	5.06E+08	1.18E-08	5.06E+08	1.10E-08	4.72E+08	1.11E-08	4.76E+08	1.39E-08	5.97E+08	1.25E-08	5.38E+08
Cs-135	2.82E-01	1.20E-09	1.25E+03	1.20E-09	1.25E+03	1.41E-09	1.47E+03	1.20E-09	1.25E+03	1.20E-09	1.25E+03	1.20E-09	1.25E+03	1.20E-09	1.25E+03	1.23E-09	1.28E+03
Cs-137	3.87E+04	8.76E-09	1.25E+09	7.84E-09	1.12E+09	8.82E-09	1.26E+09	8.30E-09	1.19E+09	7.94E-09	1.14E+09	7.93E-09	1.14E+09	9.12E-09	1.31E+09	8.63E-09	1.24E+09
Eu-154	1.83E+03	1.17E-08	7.92E+07	1.55E-08	1.05E+08	7.92E-08	5.36E+08	1.06E-07	7.18E+08	5.23E-07	3.54E+09	7.14E-09	4.83E+07	1.13E-07	7.65E+08	7.73E-08	5.23E+08
Eu-155	6.37E+02	3.56E-10	8.39E+05	6.14E-10	1.45E+06	1.19E-08	2.80E+07	1.43E-08	3.37E+07	1.52E-07	3.58E+08	2.40E-10	5.66E+05	1.11E-08	2.62E+07	1.12E-08	2.64E+07
Fe-55	2.35E+02	1.79E-10	1.56E+05	1.74E-10	1.51E+05	1.06E-09	9.22E+05	1.76E-10	1.53E+05	1.75E-10	1.52E+05	1.85E-10	1.61E+05	4.37E-10	3.80E+05	3.61E-10	3.14E+05
H-3	1.76E+02	1.73E-11	1.13E+04	1.73E-11	1.13E+04	1.73E-11	1.13E+04	1.73E-11	1.13E+04	1.73E-11	1.13E+04	1.73E-11	1.13E+04	1.73E-11	1.13E+04	1.73E-11	1.13E+04
I-129	1.36E-02	8.69E-11	4.37E+00	2.09E-10	1.05E+01	3.14E-10	1.58E+01	1.40E-10	7.04E+00	1.38E-10	6.94E+00	1.56E-06	7.85E+04	1.18E-10	5.94E+00	4.69E-08	2.36E+03
Kr-85	2.03E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nb-93m	1.22E+00	1.55E-10	7.00E+02	4.36E-11	1.97E+02	6.45E-08	2.91E+05	1.14E-10	5.15E+02	2.84E-10	1.28E+03	1.14E-11	5.15E+01	3.04E-10	1.37E+03	7.90E-09	3.57E+04
Nb-94	3.39E-02	4.42E-09	5.54E+02	2.24E-08	2.81E+03	7.48E-07	9.38E+04	2.26E-08	2.83E+03	1.97E-08	2.47E+03	2.22E-08	2.78E+03	4.45E-08	5.58E+03	1.12E-07	1.40E+04
Ni-59	7.80E-01	1.09E-10	3.15E+02	1.05E-10	3.03E+02	1.20E-09	3.46E+03	1.06E-10	3.06E+02	1.05E-10	3.03E+02	1.14E-10	3.29E+02	1.40E-10	4.04E+02	2.48E-10	7.17E+02
Ni-63	1.16E+02	2.47E-10	1.06E+05	2.47E-10	1.06E+05	3.07E-09	1.32E+06	2.47E-10	1.06E+05	2.47E-10	1.06E+05	2.47E-10	1.06E+05	3.67E-10	1.58E+05	6.22E-10	2.67E+05
Np-237	1.33E-01	2.96E-05	1.46E+07	1.69E-08	8.32E+03	1.61E-05	7.92E+06	2.62E-04	1.29E+08	3.27E-03	1.61E+09	1.34E-08	6.59E+03	2.34E-05	1.15E+07	1.46E-04	7.18E+07
Pa-231	2.94E-05	3.06E-09	3.33E-01	5.65E-09	6.15E-01	7.47E-04	8.13E+04	2.88E-04	3.13E+04	3.60E-03	3.92E+05	4.45E-09	4.84E-01	2.12E-07	2.31E+01	2.32E-04	2.53E+04
Pb-210	0.00E+00	3.18E-07	0.00E+00	3.18E-07	0.00E+00	3.18E-07	0.00E+00	3.75E-06	0.00E+00	5.47E-05	0.00E+00	3.18E-07	0.00E+00	4.69E-06	0.00E+00	3.67E-06	0.00E+00
Pd-107	5.70E-02	1.05E-13	2.21E-02	1.05E-13	2.21E-02	2.85E-08	6.01E+03	5.68E-13	1.20E-01	1.51E-12	3.18E-01	1.05E-13	2.21E-02	9.71E-11	2.05E+01	3.45E-09	7.27E+02
Pm-147	7.46E+03	8.25E-15	2.28E+02	3.60E-14	9.94E+02	7.74E-08	2.14E+09	1.61E-09	4.44E+07	2.01E-08	5.55E+08	1.98E-14	5.47E+02	1.56E-09	4.31E+07	1.06E-08	2.91E+08
Pu-238	2.11E+03	1.04E-05	8.12E+10	4.40E-10	3.44E+06	3.20E-04	2.50E+12	5.80E-05	4.53E+11	7.25E-04	5.66E+12	3.86E-10	3.01E+06	2.74E-05	2.14E+11	7.79E-05	6.08E+11
Pu-239	5.36E+01	1.20E-05	2.38E+09	3.99E-10	7.91E+04	3.23E-04	6.41E+10	6.57E-05	1.30E+10	8.21E-04	1.63E+11	3.75E-10	7.44E+04	3.02E-05	5.99E+09	8.33E-05	1.65E+10
Pu-240	1.48E+02	1.20E-05	6.57E+09	4.33E-10	2.37E+05	3.23E-04	1.77E+11	6.57E-05	3.60E+10	8.21E-04	4.50E+11	3.76E-10	2.06E+05	3.02E-05	1.65E+10	8.33E-05	4.56E+10
Pu-241	2.25E+04	2.76E-07	2.30E+10	2.14E-11	1.78E+06	3.18E-06	2.65E+11	1.43E-06	1.19E+11	1.78E-05	1.48E+12	9.15E-12	7.62E+05	6.02E-07	5.01E+10	1.34E-06	1.11E+11
Pu-242	1.26E+00	1.14E-05	5.31E+07	4.35E-10	2.03E+03	3.07E-04	1.43E+09	6.25E-05	2.91E+08	7.81E-04	3.64E+09	3.71E-10	1.73E+03	2.86E-05	1.33E+08	7.92E-05	3.69E+08
Ra-226	0.00E+00	1.02E-07	0.00E+00	1.02E-07	0.00E+00	1.61E-05	0.00E+00	6.64E-07	0.00E+00	7.59E-06	0.00E+00	1.02E-07	0.00E+00	1.07E-07	0.00E+00	2.32E-06	0.00E+00
Ra-228	0.00E+00	1.83E-07	0.00E+00	1.84E-07	0.00E+00	7.22E-06	0.00E+00	7.38E-07	0.00E+00	6.51E-06	0.00E+00	1.83E-07	0.00E+00	1.87E-07	0.00E+00	1.29E-06	0.00E+00
Ru-106	3.29E+03	1.30E-09	1.58E+07	1.78E-09	2.17E+07	1.04E-06	1.27E+10	1.76E-09	2.14E+07	1.61E-09	1.96E+07	1.72E-09	2.09E+07	1.20E-08	1.46E+08	1.29E-07	1.57E+09
Sb-125	6.21E+02	3.60E-10	8.27E+05	4.16E-10	9.56E+05	2.17E-08	4.99E+07	5.35E-10	1.23E+06	9.78E-10	2.25E+06	3.24E-10	7.44E+05	1.45E-09	3.33E+06	3.30E-09	7.58E+06
Se-79	2.89E-02	5.98E-10	6.39E+01	5.98E-10	6.39E+01	9.81E-09	1.05E+03	5.98E-10	6.39E+01	5.98E-10	6.39E+01	5.98E-10	6.39E+01	3.77E-09	4.03E+02	2.66E-09	2.84E+02
Sm-147	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.26E-06	0.00E+00	2.75E-05	0.00E+00	3.44E-04	0.00E+00	0.00E+00	0.00E+00	1.89E-05	0.00E+00	2.02E-05	0.00E+00
Sm-151	8.22E+01	4.03E-14	1.23E+01	1.49E-13	4.53E+01	3.26E-09	9.91E+05	1.10E-08	3.35E+06	1.38E-07	4.20E+07	1.32E-14	4.01E+00	7.51E-09	2.28E+06	8.10E-09	2.46E+06
Sn-126	2.52E-01	4.95E-09	4.62E+03	5.39E-09	5.03E+03	1.51E-07	1.41E+05	1.69E-08	1.58E+04	3.33E-08	3.10E+04	4.90E-09	4.57E+03	1.20E-08	1.12E+04	2.69E-08	2.51E+04
Sr-90	2.52E+04	2.64E-09	2.46E+08	2.64E-09	2.46E+08	3.73E-09	3.48E+08	3.36E-07	3.13E+10	7.27E-07	6.78E+10	2.64E-09	2.46E+08	3.36E-09	3.13E+08	6.47E-08	6.03E+09
Tc-99	5.35E+00	3.99E-11	7.90E+02	3.99E-11	7.90E+02	1.67E-08	3.31E+05	3.99E-11	7.90E+02	3.99E-11	7.90E+02	1.07E-09	2.12E+04	6.26E-10	1.24E+04	2.25E-09	4.45E+04
Th-229	0.00E+00	1.18E-06	0.00E+00	1.18E-06	0.00E+00	1.99E-03	0.00E+00	4.60E-04	0.00E+00	5.73E-03	0.00E+00	1.18E-06	0.00E+00	3.02E-06	0.00E+00	4.67E-04	0.00E+00
Th-230	2.05E-05	1.72E-07	1.30E+01	1.72E-07	1.30E+01	3.00E-04	2.28E+04	6.99E-05	5.30E+03	8.71E-04	6.61E+04	1.72E-07	1.30E+01	4.48E-07	3.40E+01	7.07E-05	5.36E+03
Th-232	0.00E+00	5.98E-07	0.00E+00	6.14E-07	0.00E+00	9.40E-04	0.00E+00	4.01E-04	0.00E+00	4.99E-03	0.00E+00	5.99E-07	0.00E+00	1.51E-06	0.00E+00	3.11E-04	0.00E+00
U-232	2.00E-02	1.69E-08	1.25E+03	2.66E-08	1.97E+03	1.48E-03	1.10E+08	4.68E-07	3.46E+04	7.14E-06	5.28E+05	2.43E-08	1.80E+03	5.86E-07	4.34E+04	1.78E-04	1.32E+07
U-233	0.00E+00	2.69E-09	0.00E+00	2.73E-09	0.00E+00	3.04E-04	0.00E+00	7.39E-08	0.00E+00	1.16E-06	0.00E+00	2.70E-09	0.00E+00	1.08E-07	0.00E+00	3.66E-05	0.00E+00
U-234	2.26E-01	2.65E-09	2.22E+03	2.68E-09	2.24E+03	2.98E-04	2.49E+08	7.22E-08	6.04E+04	1.13E-06	9.45E+05	2.65E-09	2.22E+03	1.06E-07	8.86E+04	3.58E-05	3.00E+07
U-235	9.40E-04	2.84E-09	9.88E+00	5.37E-09	1.87E+01	2.76E-04	9.60E+05	7.15E-08	2.49E+02	1.05E-06	3.65E+03	4.11E-09	1.43E+01	1.02E-07	3.55E+02	3.32E-05	1.15E+05
U-236	9.55E-02	2.51E-09	8.87E+02	2.54E-09	8.98E+02	2.82E-04	9.96E+07	6.83E-08	2.41E+04	1.07E-06	3.78E+05	2.51E-09	8.87E+02	1.19E-09	4.20E+02	3.39E-05	1.20E+07
U-238	6.07E-02	2.42E-09	5.44E+02	2.91E-09	6.54E+02	2.66E-04	5.97E+07	6.88E-08	1.55E+04	1.01E-06	2.27E+05	2.73E-09	6.13E+02	9.61E-08	2.16E+04	3.20E-05	7.18E+06
Zr-93	6.03E-01	5.58E-12	1.24E+01	1.20E-11	2.68E+01	3.30E-09	7.36E+03	4.49E-08	1.00E+05	5.54E-07	1.24E+06	4.45E-12	9.93E+00	1.54E-10	3.44E+02	2.25E-08	5.01E+04

Dose Coefficients for Air Submersion from Federal Guidance Report #12 (Eckerman and Ryman 1993, Table 2.1)

Nuclide	Dose Coefficient (Sv-m^3/Bq-s)									
	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Effective	Skin	Eye
H-3	0.00E+00	0.00E+00	2.75E-18	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.31E-19	0.00E+00	0.00E+00
Kr-85	1.17E-16	1.34E-16	1.14E-16	1.09E-16	2.20E-16	1.18E-16	1.09E-16	1.19E-16	1.32E-14	0.00E+00

Submersion Dose Rate (rem-m^3/FA-s) = ST (Ci/FA) x conv (rem-Bq/Ci-Sv) x DC (Sv-m^3/Bq-s)

conv: 3.70E+12 Sv/Bq = rem/Ci

DC = Dose Coefficient (Sv-m^3/Bq-s)
Ci = Curies
FA = Fuel Assemblies
ST = Source Term (Ci/FA)
m^3 = cubic meters
s = seconds
Sv = Sieverts
Bq = Becquerels
conv = conversion factor (rem-Bq/Ci-Sv)

Nuclide	Source Term (Ci/FA)			
	Avg PWR	Avg BWR	Max PWR	Max BWR
H-3	1.14E+02	3.95E+01	4.72E+02	1.76E+02
Kr-85	1.13E+03	3.81E+02	5.63E+03	2.03E+03

Average PWR Fuel

Nuclide	Submersion Dose Rate (rem-m^3/FA-s)									
	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Effective	Skin	Eye
H-3	0.00E+00	0.00E+00	1.16E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.40E-04	0.00E+00	0.00E+00
Kr-85	4.89E-01	5.60E-01	4.77E-01	4.56E-01	9.20E-01	4.93E-01	4.56E-01	4.98E-01	5.52E+01	0.00E+00

Average BWR Fuel

Nuclide	Submersion Dose Rate (rem-m^3/FA-s)									
	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Effective	Skin	Eye
H-3	0.00E+00	0.00E+00	4.02E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.84E-05	0.00E+00	0.00E+00
Kr-85	1.65E-01	1.89E-01	1.61E-01	1.54E-01	3.10E-01	1.66E-01	1.54E-01	1.68E-01	1.86E+01	0.00E+00

Maximum PWR Fuel

Nuclide	Submersion Dose Rate (rem-m^3/FA-s)									
	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Effective	Skin	Eye
H-3	0.00E+00	0.00E+00	4.80E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.78E-04	0.00E+00	0.00E+00
Kr-85	2.44E+00	2.79E+00	2.37E+00	2.27E+00	4.58E+00	2.46E+00	2.27E+00	2.48E+00	2.75E+02	0.00E+00

Maximum BWR Fuel

Nuclide	Submersion Dose Rate (rem-m^3/FA-s)									
	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Effective	Skin	Eye
H-3	0.00E+00	0.00E+00	1.79E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.16E-04	0.00E+00	0.00E+00
Kr-85	8.79E-01	1.01E+00	8.56E-01	8.19E-01	1.65E+00	8.86E-01	8.19E-01	8.94E-01	9.91E+01	0.00E+00

Validation Test Cases for Formulas Contained in this Workbook

Worksheet	Cell Range	Test Cell	Formula	Input	Output	Hand-Calculated Results*
Avg_PWR Dose	D6:D61, F6:F61, H6:H61, J6:J61, L6:L61, N6:N61, O6:O61, P6:P61, Q6:Q61, R6:R61	D6	=$B6*C6*3.7E12	B6=1.61E-5, C6=3.56E-5	D6=2.12E+3	D6=2.120E+3
Max_PWR Dose	D6:D61, F6:F61, H6:H61, J6:J61, L6:L61, N6:N61, O6:O61, P6:P61, Q6:Q61, R6:R61	D7	=$B7*C7*3.7E12	B7=8.71E+2, C7=3.25E-5	D7=1.05E11	D7=1.047E11
Avg_BWR Dose	D6:D61, F6:F61, H6:H61, J6:J61, L6:L61, N6:N61, O6:O61, P6:P61, Q6:Q61, R6:R61	D7	=$B7*C7*3.7E12	B7=5.58E+2, C7=3.25E-5	D7=6.71E10	D7=6.710E10
Max_BWR Dose	D6:D61, F6:F61, H6:H61, J6:J61, L6:L61, N6:N61, O6:O61, P6:P61, Q6:Q61, R6:R61	D7	=$B7*C7*3.7E12	B7=2.66E+2, C7=3.25E-5	D7=3.20E10	D7=3.199E10
Submersion Dose	B24:K25	D24	=$D$7*$B$12*$B$17	D7=2.75E-18, B12=3.7E12, B17=1.14E2	D24=1.16E-3	D24=1.160E-3
Submersion Dose	B30:K31	D30	=$D$7*$B$12*$C$17	D7=2.75E-18, B12=3.7E12, C17=3.95E+1	D30=4.02E-4	D30=4.019E-4
Submersion Dose	B37:K38	D37	=$D$7*$B$12*$D$17	D7=2.75E-18, B12=3.7E12, D17=4.72E2	D37=4.80E-3	D37=4.803E-3
Submersion Dose	B44:K45	D44	=$D$7*$B$12*$E$17	D7=2.75E-18, B12=3.7E12, E17=1.76E2	D44=1.79E-3	D44=1.791E-3

* Output values may differ slightly from hand calculations due to rounding errors. These differences are acceptable for the range of input values used in this calculation.

Attachment IX

Category 1 Event Release Calculations

The following data in this attachment is from file **SR Cat. 1 Release_Rev01.xls** (Attachment I):

Worksheet	Description	Pages
Events-Frequencies	Event Frequencies and Material-At-Risk (MAR)	IX-2
Avg Source	Average Source Terms for PWR & BWR Fuel	IX-3
CRUD Source	Crud Source Term Calculations	IX-4
χ-Q Values	χ/Q Values for Category 1 Event Releases	IX-5
RFs	CSNF Release Fractions	IX-6
Normal Releases	Normal Releases from Surface and Subsurface	IX-7
Inputs	Input Parameters for each Category 1 Event	IX-8 to IX-21
Cat. 1 DBE Release	Output Releases for each Category 1 Event	IX-22 to IX-35
Total Cat. 1 DBE Release	Total Annual Releases for All Category 1 Events	IX-36 to IX-37
Test Cases	Validation Test Cases for Formulas contained in this workbook	IX-38

Category 1 Event Frequencies and MAR

Event #	Category 1 Events	Occurs in Pool?	Material at Risk (# SFAs)		Sequence Frequency (per year)
			PWR	BWR	
1-01	SFA Drop Onto Another SFA in Cask	Y	2	2	2.34E-01
1-02	SFA Collision	Y	1	1	3.90E-02
1-03	SFA Drop Onto Empty Basket	Y	1	1	4.22E-02
1-04	SFA Drop Onto Another SFA in Basket Staging Rack (Lowering Into)	Y	2	2	1.92E-01
1-05	Basket Drop Onto Another Basket in Basket Staging Rack (Lifting Out)	Y	8	16	4.10E-02
1-06	Basket Drop Onto Another Basket in Pool (Transfer Into Pool Storage)	Y	8	16	4.10E-02
1-07	Basket Drop Onto Another Basket in Pool (Transfer Out of Pool Storage)	Y	8	16	4.10E-02
1-08	Basket Drop Onto Transfer Cart or Pool Floor	Y	4	8	4.10E-02
1-09	Basket Drop Back Into Pool	Y	4	8	4.10E-02
1-10	Basket Drop Onto ATS Hot Cell Floor	N	4	8	4.10E-02
1-11	Basket Drop Onto Another Basket in Dryer	N	8	16	4.10E-02
1-12	SFA Drop Onto Another SFA in Dryer	N	2	2	2.34E-01
1-13	SFA Drop Onto ATS Hot Cell Floor	N	1	1	2.34E-01
1-14	SFA Drop Onto Another SFA in DC	N	2	2	2.34E-01

Average Source Terms for PWR and BWR SFAs

Isotope	Average PWR Source Terms (Curies/FA)	Average BWR Source Terms (Curies/FA)
Ac-227	1.61E-05	0.00E+00
Am-241	1.98E+03	5.58E+02
Am-242m	6.39E+00	2.17E+00
Am-243	2.20E+01	5.35E+00
C-14	3.32E-01	1.75E-01
Cd-113m	7.66E+00	2.26E+00
Cl-36	6.80E-03	2.93E-03
Cm-242	5.27E+00	1.79E+00
Cm-243	1.03E+01	2.48E+00
Cm-244	1.36E+03	2.56E+02
Cm-245	3.07E-01	4.04E-02
Cm-246	1.04E-01	1.45E-02
Co-60	3.13E+02	4.40E+01
Cs-134	2.52E+01	6.32E+00
Cs-135	3.50E-01	1.39E-01
Cs-137	4.11E+04	1.39E+04
Eu-154	6.71E+02	1.80E+02
Eu-155	5.16E+01	1.64E+01
Fe-55	3.47E+00	1.09E+00
H-3	1.14E+02	3.95E+01
I-129	2.20E-02	7.43E-03
Kr-85	1.13E+03	3.81E+02
Nb-93m	1.30E+01	4.74E-01
Nb-94	8.39E-01	1.87E-02
Ni-59	2.09E+00	5.03E-01
Ni-63	2.52E+02	5.87E+01
Np-237	2.47E-01	6.89E-02
Pa-231	2.97E-05	1.39E-05
Pb-210	0.00E+00	0.00E+00
Pd-107	8.41E-02	2.65E-02
Pm-147	1.19E+02	3.98E+01
Pu-238	2.29E+03	5.85E+02
Pu-239	1.77E+02	5.35E+01
Pu-240	3.18E+02	1.14E+02
Pu-241	2.47E+04	6.78E+03
Pu-242	1.64E+00	5.09E-01
Ra-226	0.00E+00	0.00E+00
Ra-228	0.00E+00	0.00E+00
Ru-106	1.23E-02	3.00E-03
Sb-125	9.71E+00	2.89E+00
Se-79	4.57E-02	1.59E-02
Sm-147	0.00E+00	0.00E+00
Sm-151	2.11E+02	5.39E+01
Sn-126	3.85E-01	1.27E-01
Sr-90	2.72E+04	9.54E+03
Tc-99	8.99E+00	3.20E+00
Th-229	0.00E+00	0.00E+00
Th-230	1.48E-04	6.09E-05
Th-232	0.00E+00	0.00E+00
U-232	2.05E-02	4.64E-03
U-233	4.07E-05	1.14E-05
U-234	6.77E-01	2.49E-01
U-235	7.36E-03	2.62E-03
U-236	1.72E-01	6.26E-02
U-238	1.48E-01	6.32E-02
Zr-93	8.94E-01	3.38E-01

Average PWR Characteristics:
4.0% Enrichment
48 GWd/MTU Burnup
25 Years Decay

Average BWR Characteristics:
3.5% Enrichment
40 GWd/MTU Burnup
25 Years Decay

Crud Source Term Calculations

Fe-55 Included In Crud Calc. (Y/N):	Y	
Crud Decay Time (years):	25	
Fe-55 PWR Surface Activity (uCi/cm^2) =	10.3	{values are corrected for half-life & avg surface activity if #
Fe-55 BWR Surface Activity (uCi/cm^2) =	13.0	FA>1 (CRWMS M&O 1999d, Table 8-2)}
Co-60 PWR Surface Activity (uCi/cm^2) =	2.6	
Co-60 BWR Surface Activity (uCi/cm^2) =	23.4	
Bounding PWR Surface Area (cm^2) =	449,003	(CRWMS M&O 1999h, p. 25)
Bounding BWR Surface Area (cm^2) =	168,148	(CRWMS M&O 1999b, p. 46)

Conversions		Co-60 Half Life	Fe-55 Half Life
Bq per uCi =	3.70E+04	5.271 y	2.73 y
rem per Sv =	100		

Crud Source (Ci/FA)

Fe-55 PWR	4.6E+00
Fe-55 BWR	2.2E+00
Co-60 PWR	1.2E+00
Co-60 BWR	3.9E+00

Atmospheric Dispersion Factors (X/Qs) for Category 1 Releases

Chronic Release from Surface WHB		
Distance (m)	Chronic X/Q (s/m^3)	Reference
10,000	2.12E-07	CRWMS M&O (1999c), p. 25, Table 6c, Sector 16
20,000	8.12E-08	CRWMS M&O (1999c), p. 25, Table 6c, Sector 16
11,000	1.99E-07	Interpolated

Chronic Release from Subsurface		
Distance (m)	Chronic X/Q (s/m^3)	Reference
7,500	3.19E-07	CRWMS M&O (1999c), p. 25, Table 6c, Sector 16
10,000	2.12E-07	CRWMS M&O (1999c), p. 25, Table 6c, Sector 16
8,000	2.98E-07	Interpolated

CSNF Release Fractions in Air

Notes:	(1)	(2)	(3)	(4)	(5)	(6)
Nuclide	Cladding Damage Fraction	Airborne Release Fraction	Local Dep.	Clad Rel. Fraction	Respirable Fraction	Effective Release Fraction
H-3	1.0	0.3	1.0	1.0	1.0	3.00E-01
Kr-85	1.0	0.3	1.0	1.0	1.0	3.00E-01
I-129	1.0	0.3	1.0	1.0	1.0	3.00E-01
Cs	1.0	2.00E-04	1.0	1.0	1.0	2.00E-04
Sr	1.0	3.00E-05	1.0	1.0	1.0	3.00E-05
Ru	1.0	3.00E-05	1.0	1.0	1.0	3.00E-05
Crud	1.0	1.00E+00	1.0	1.0	1.0	1.00E+00
Particulates	1.0	3.00E-05	1.0	1.0	1.0	3.00E-05

CSNF Release Fractions in Water (Assumption 3.21)

Notes:	(1)	(2)	(3)	(4)	(5)	(6)
Nuclide	Cladding Damage Fraction	Airborne Release Fraction	Local Dep.	Clad Rel. Fraction	Respirable Fraction	Effective Release Fraction
H-3	1.0	0.3	1.0	1.0	1.0	3.00E-01
Kr-85	1.0	0.3	1.0	1.0	1.0	3.00E-01
I-129	1.0	0.3	1.0	1.0	1.0	3.00E-01
Cs	1.0	0.0	1.0	1.0	1.0	0.00E+00
Sr	1.0	0.0	1.0	1.0	1.0	0.00E+00
Ru	1.0	0.0	1.0	1.0	1.0	0.00E+00
Crud	1.0	0.0	1.0	1.0	1.0	0.00E+00
Particulates	1.0	0.0	1.0	1.0	1.0	0.00E+00

Notes:

(1) A fraction of 1.0 indicates that all the cladding is failed.

(2) ARFs in air are taken from Table 8-1 of CRWMS M&O (1999d); ARFs in water are based on Assumption 3.21.

(3) A factor of 1.0 indicates no local deposition.

(4) A factor of 1.0 indicates no retention in by the cladding.

(5) Respirable fractions are conservatively taken to be 1.0 for inhalation and ingestion (Assumption 3.24).

(6) Effective release fractions are obtained by multiplying columns (1) through (5)

Normal (Chronic) Releases from Surface & Subsurface Facilities

Normal Ops Release - Surface (Ci/yr)		Source
Kr-85	4.01E+03	(CRWMS M&O 2000a)

Normal Ops Release - Subsurface (Ci/yr)		Source
N-16	2.909E-03	(CRWMS M&O 2000b)
Ar-41	5.728E+01	
Na-24	6.471E-03	
Al-28	3.963E-03	
Si-31	7.170E-04	
K-42	8.041E-04	
Fe-55	1.492E-04	

Input Parameters for Category 1 Release Calculations:

Fuel Type:	Average PWR	
Event #:	1-01	
Description:	SFA Drop Onto Another SFA in Cask	
Event Frequency:	2.34E-01	
Number of Fuel Assemblies Damaged:	2	
Does the Event Occur in a Pool?	Yes / No	
HEPA Filter Release Fraction:	0.01	99% Particulate Retention (Assumption 3.23)

Input Parameters for Category 1 Release Calculations:

Fuel Type:	Average PWR	
Event #:	1-02	
Description:	SFA Collision	
Event Frequency:	3.90E-02	
Number of Fuel Assemblies Damaged:	1	
Does the Event Occur in a Pool?	Yes / No	
HEPA Filter Release Fraction:	0.01	99% Particulate Retention (Assumption 3.23)

Input Parameters for Category 1 Release Calculations:

Fuel Type:	Average PWR	
Event #:	1-03	
Description:	SFA Drop Onto Empty Basket	
Event Frequency:	4.22E-02	
Number of Fuel Assemblies Damaged:	1	
Does the Event Occur in a Pool?	Yes / No	
HEPA Filter Release Fraction:	0.01	99% Particulate Retention (Assumption 3.23)

Input Parameters for Category 1 Release Calculations:

Fuel Type:	Average PWR	
Event #:	1-04	
Description:	SFA Drop Onto Another SFA in Basket Staging Rack (Lowering Into)	
Event Frequency:	1.92E-01	
Number of Fuel Assemblies Damaged:	2	
Does the Event Occur in a Pool?	Yes / No	
HEPA Filter Release Fraction:	0.01	99% Particulate Retention (Assumption 3.23)

Input Parameters for Category 1 Release Calculations:

Fuel Type:	Average PWR	
Event #:	1-05	
Description:	Basket Drop Onto Another Basket in Basket Staging Rack (Lifting Out)	
Event Frequency:	4.10E-02	
Number of Fuel Assemblies Damaged:	8	
Does the Event Occur in a Pool?	Yes / No	
HEPA Filter Release Fraction:	0.01	99% Particulate Retention (Assumption 3.23)

Input Parameters for Category 1 Release Calculations:

Fuel Type:	Average PWR	
Event #:	1-06	
Description:	Basket Drop Onto Another Basket in Pool (Transfer Into Pool Storage)	
Event Frequency:	4.10E-02	
Number of Fuel Assemblies Damaged:	8	
Does the Event Occur in a Pool?	Yes / No	
HEPA Filter Release Fraction:	0.01	99% Particulate Retention (Assumption 3.23)

Input Parameters for Category 1 Release Calculations:

Fuel Type:	Average PWR	
Event #:	1-07	
Description:	Basket Drop Onto Another Basket in Pool (Transfer Out of Pool Storage)	
Event Frequency:	4.10E-02	
Number of Fuel Assemblies Damaged:	8	
Does the Event Occur in a Pool?	Yes / No	
HEPA Filter Release Fraction:	0.01	99% Particulate Retention (Assumption 3.23)

Input Parameters for Category 1 Release Calculations:		
Fuel Type:	Average PWR	
Event #:	1-08	
Description:	Basket Drop Onto Transfer Cart or Pool Floor	
Event Frequency:	4.10E-02	
Number of Fuel Assemblies Damaged:	4	
Does the Event Occur in a Pool?	Yes / No	
HEPA Filter Release Fraction:	0.01	99% Particulate Retention (Assumption 3.23)

Input Parameters for Category 1 Release Calculations:		
Fuel Type:	Average PWR	
Event #:	1-09	
Description:	Basket Drop Back Into Pool	
Event Frequency:	4.10E-02	
Number of Fuel Assemblies Damaged:	4	
Does the Event Occur in a Pool?	Yes / No	
HEPA Filter Release Fraction:	0.01	99% Particulate Retention (Assumption 3.23)

Input Parameters for Category 1 Release Calculations:

Fuel Type:	Average PWR	
Event #:	1-10	
Description:	Basket Drop Onto ATS Hot Cell Floor	
Event Frequency:	4.10E-02	
Number of Fuel Assemblies Damaged:	4	
Does the Event Occur in a Pool?	Yes / No	
HEPA Filter Release Fraction:	0.01	99% Particulate Retention (Assumption 3.23)

Input Parameters for Category 1 Release Calculations:

Fuel Type:	Average PWR	
Event #:	1-11	
Description:	Basket Drop Onto Another Basket in Dryer	
Event Frequency:	4.10E-02	
Number of Fuel Assemblies Damaged:	8	
Does the Event Occur in a Pool?	Yes / No	
HEPA Filter Release Fraction:	0.01	99% Particulate Retention (Assumption 3.23)

Input Parameters for Category 1 Release Calculations:

Fuel Type:	Average PWR	
Event #:	1-12	
Description:	SFA Drop Onto Another SFA in Dryer	
Event Frequency:	2.34E-01	
Number of Fuel Assemblies Damaged:	2	
Does the Event Occur in a Pool?	Yes / No	
HEPA Filter Release Fraction:	0.01	99% Particulate Retention (Assumption 3.23)

Input Parameters for Category 1 Release Calculations:

Fuel Type:	Average PWR	
Event #:	1-13	
Description:	SFA Drop Onto ATS Hot Cell Floor	
Event Frequency:	2.34E-01	
Number of Fuel Assemblies Damaged:	1	
Does the Event Occur in a Pool?	Yes / No	
HEPA Filter Release Fraction:	0.01	99% Particulate Retention (Assumption 3.23)

Input Parameters for Category 1 Release Calculations:

Fuel Type:	Average PWR	
Event #:	1-14	
Description:	SFA Drop Onto Another SFA in DC	
Event Frequency:	2.34E-01	
Number of Fuel Assemblies Damaged:	2	
Does the Event Occur in a Pool?	Yes / No	
HEPA Filter Release Fraction:	0.01	99% Particulate Retention (Assumption 3.23)

Category 1 Releases

Event: 1-01 SFA Drop Onto Another SFA in Cask

Source: Average PWR

Nuclide	Source Term (Ci/FA)	# of FA's/event	Frequency (events/yr)	Mitigation Factor	Release Fraction	Annual Cat. 1 DBE Release (Ci/yr)
Co-60	1.17E+00	2	2.34E-01	0.01	0.00E+00	0.00E+00
Fe-55	4.64E+00	2	2.34E-01	0.01	0.00E+00	0.00E+00
Ac-227	1.61E-05	2	2.34E-01	0.01	0.00E+00	0.00E+00
Am-241	1.98E+03	2	2.34E-01	0.01	0.00E+00	0.00E+00
Am-242m	6.39E+00	2	2.34E-01	0.01	0.00E+00	0.00E+00
Am-243	2.20E+01	2	2.34E-01	0.01	0.00E+00	0.00E+00
C-14	3.32E-01	2	2.34E-01	0.01	0.00E+00	0.00E+00
Cd-113m	7.66E+00	2	2.34E-01	0.01	0.00E+00	0.00E+00
Cl-36	6.80E-03	2	2.34E-01	0.01	0.00E+00	0.00E+00
Cm-242	5.27E+00	2	2.34E-01	0.01	0.00E+00	0.00E+00
Cm-243	1.03E+01	2	2.34E-01	0.01	0.00E+00	0.00E+00
Cm-244	1.36E+03	2	2.34E-01	0.01	0.00E+00	0.00E+00
Cm-245	3.07E-01	2	2.34E-01	0.01	0.00E+00	0.00E+00
Cm-246	1.04E-01	2	2.34E-01	0.01	0.00E+00	0.00E+00
Co-60	3.13E+02	2	2.34E-01	0.01	0.00E+00	0.00E+00
Cs-134	2.52E+01	2	2.34E-01	0.01	0.00E+00	0.00E+00
Cs-135	3.50E-01	2	2.34E-01	0.01	0.00E+00	0.00E+00
Cs-137	4.11E+04	2	2.34E-01	0.01	0.00E+00	0.00E+00
Eu-154	6.71E+02	2	2.34E-01	0.01	0.00E+00	0.00E+00
Eu-155	5.16E+01	2	2.34E-01	0.01	0.00E+00	0.00E+00
Fe-55	3.47E+00	2	2.34E-01	0.01	0.00E+00	0.00E+00
H-3	1.14E+02	2	**2.34E-01**	**1.0**	3.00E-01	1.60E+01
I-129	2.20E-02	2	**2.34E-01**	**1.0**	3.00E-01	3.09E-03
Kr-85	1.13E+03	2	**2.34E-01**	**1.0**	3.00E-01	1.59E+02
Nb-93m	1.30E+01	2	2.34E-01	0.01	0.00E+00	0.00E+00
Nb-94	8.39E-01	2	2.34E-01	0.01	0.00E+00	0.00E+00
Ni-59	2.09E+00	2	2.34E-01	0.01	0.00E+00	0.00E+00
Ni-63	2.52E+02	2	2.34E-01	0.01	0.00E+00	0.00E+00
Np-237	2.47E-01	2	2.34E-01	0.01	0.00E+00	0.00E+00
Pa-231	2.97E-05	2	2.34E-01	0.01	0.00E+00	0.00E+00
Pb-210	0.00E+00	2	2.34E-01	0.01	0.00E+00	0.00E+00
Pd-107	8.41E-02	2	2.34E-01	0.01	0.00E+00	0.00E+00
Pm-147	1.19E+02	2	2.34E-01	0.01	0.00E+00	0.00E+00
Pu-238	2.29E+03	2	2.34E-01	0.01	0.00E+00	0.00E+00
Pu-239	1.77E+02	2	2.34E-01	0.01	0.00E+00	0.00E+00
Pu-240	3.18E+02	2	2.34E-01	0.01	0.00E+00	0.00E+00
Pu-241	2.47E+04	2	2.34E-01	0.01	0.00E+00	0.00E+00
Pu-242	1.64E+00	2	2.34E-01	0.01	0.00E+00	0.00E+00
Ra-226	0.00E+00	2	2.34E-01	0.01	0.00E+00	0.00E+00
Ra-228	0.00E+00	2	2.34E-01	0.01	0.00E+00	0.00E+00
Ru-106	1.23E-02	2	2.34E-01	0.01	0.00E+00	0.00E+00
Sb-125	9.71E+00	2	2.34E-01	0.01	0.00E+00	0.00E+00
Se-79	4.57E-02	2	2.34E-01	0.01	0.00E+00	0.00E+00
Sm-147	0.00E+00	2	2.34E-01	0.01	0.00E+00	0.00E+00
Sm-151	2.11E+02	2	2.34E-01	0.01	0.00E+00	0.00E+00
Sn-126	3.85E-01	2	2.34E-01	0.01	0.00E+00	0.00E+00
Sr-90	2.72E+04	2	2.34E-01	0.01	0.00E+00	0.00E+00
Tc-99	8.99E+00	2	2.34E-01	0.01	0.00E+00	0.00E+00
Th-229	0.00E+00	2	2.34E-01	0.01	0.00E+00	0.00E+00
Th-230	1.48E-04	2	2.34E-01	0.01	0.00E+00	0.00E+00
Th-232	0.00E+00	2	2.34E-01	0.01	0.00E+00	0.00E+00
U-232	2.05E-02	2	2.34E-01	0.01	0.00E+00	0.00E+00
U-233	4.07E-05	2	2.34E-01	0.01	0.00E+00	0.00E+00
U-234	6.77E-01	2	2.34E-01	0.01	0.00E+00	0.00E+00
U-235	7.36E-03	2	2.34E-01	0.01	0.00E+00	0.00E+00
U-236	1.72E-01	2	2.34E-01	0.01	0.00E+00	0.00E+00
U-238	1.48E-01	2	2.34E-01	0.01	0.00E+00	0.00E+00
Zr-93	8.94E-01	2	2.34E-01	0.01	0.00E+00	0.00E+00

Category 1 Releases

Event: 1-02 SFA Collision

Source: **Average PWR**

Nuclide	Source Term (Ci/FA)	# of FA's/event	Frequency (events/yr)	Mitigation Factor	Release Fraction	Annual Cat. 1 DBE Release (Ci/yr)
Co-60	2.35E+00	1	3.90E-02	0.01	0.00E+00	0.00E+00
Fe-55	4.64E+00	1	3.90E-02	0.01	0.00E+00	0.00E+00
Ac-227	1.61E-05	1	3.90E-02	0.01	0.00E+00	0.00E+00
Am-241	1.98E+03	1	3.90E-02	0.01	0.00E+00	0.00E+00
Am-242m	6.39E+00	1	3.90E-02	0.01	0.00E+00	0.00E+00
Am-243	2.20E+01	1	3.90E-02	0.01	0.00E+00	0.00E+00
C-14	3.32E-01	1	3.90E-02	0.01	0.00E+00	0.00E+00
Cd-113m	7.66E+00	1	3.90E-02	0.01	0.00E+00	0.00E+00
Cl-36	6.80E-03	1	3.90E-02	0.01	0.00E+00	0.00E+00
Cm-242	5.27E+00	1	3.90E-02	0.01	0.00E+00	0.00E+00
Cm-243	1.03E+01	1	3.90E-02	0.01	0.00E+00	0.00E+00
Cm-244	1.36E+03	1	3.90E-02	0.01	0.00E+00	0.00E+00
Cm-245	3.07E-01	1	3.90E-02	0.01	0.00E+00	0.00E+00
Cm-246	1.04E-01	1	3.90E-02	0.01	0.00E+00	0.00E+00
Co-60	3.13E+02	1	3.90E-02	0.01	0.00E+00	0.00E+00
Cs-134	2.52E+01	1	3.90E-02	0.01	0.00E+00	0.00E+00
Cs-135	3.50E-01	1	3.90E-02	0.01	0.00E+00	0.00E+00
Cs-137	4.11E+04	1	3.90E-02	0.01	0.00E+00	0.00E+00
Eu-154	6.71E+02	1	3.90E-02	0.01	0.00E+00	0.00E+00
Eu-155	5.16E+01	1	3.90E-02	0.01	0.00E+00	0.00E+00
Fe-55	3.47E+00	1	3.90E-02	0.01	0.00E+00	0.00E+00
H-3	1.14E+02	1	**3.90E-02**	**1.0**	3.00E-01	1.34E+00
I-129	2.20E-02	1	**3.90E-02**	**1.0**	3.00E-01	2.58E-04
Kr-85	1.13E+03	1	**3.90E-02**	**1.0**	3.00E-01	1.32E+01
Nb-93m	1.30E+01	1	3.90E-02	0.01	0.00E+00	0.00E+00
Nb-94	8.39E-01	1	3.90E-02	0.01	0.00E+00	0.00E+00
Ni-59	2.09E+00	1	3.90E-02	0.01	0.00E+00	0.00E+00
Ni-63	2.52E+02	1	3.90E-02	0.01	0.00E+00	0.00E+00
Np-237	2.47E-01	1	3.90E-02	0.01	0.00E+00	0.00E+00
Pa-231	2.97E-05	1	3.90E-02	0.01	0.00E+00	0.00E+00
Pb-210	0.00E+00	1	3.90E-02	0.01	0.00E+00	0.00E+00
Pd-107	8.41E-02	1	3.90E-02	0.01	0.00E+00	0.00E+00
Pm-147	1.19E+02	1	3.90E-02	0.01	0.00E+00	0.00E+00
Pu-238	2.29E+03	1	3.90E-02	0.01	0.00E+00	0.00E+00
Pu-239	1.77E+02	1	3.90E-02	0.01	0.00E+00	0.00E+00
Pu-240	3.18E+02	1	3.90E-02	0.01	0.00E+00	0.00E+00
Pu-241	2.47E+04	1	3.90E-02	0.01	0.00E+00	0.00E+00
Pu-242	1.64E+00	1	3.90E-02	0.01	0.00E+00	0.00E+00
Ra-226	0.00E+00	1	3.90E-02	0.01	0.00E+00	0.00E+00
Ra-228	0.00E+00	1	3.90E-02	0.01	0.00E+00	0.00E+00
Ru-106	1.23E-02	1	3.90E-02	0.01	0.00E+00	0.00E+00
Sb-125	9.71E+00	1	3.90E-02	0.01	0.00E+00	0.00E+00
Se-79	4.57E-02	1	3.90E-02	0.01	0.00E+00	0.00E+00
Sm-147	0.00E+00	1	3.90E-02	0.01	0.00E+00	0.00E+00
Sm-151	2.11E+02	1	3.90E-02	0.01	0.00E+00	0.00E+00
Sn-126	3.85E-01	1	3.90E-02	0.01	0.00E+00	0.00E+00
Sr-90	2.72E+04	1	3.90E-02	0.01	0.00E+00	0.00E+00
Tc-99	8.99E+00	1	3.90E-02	0.01	0.00E+00	0.00E+00
Th-229	0.00E+00	1	3.90E-02	0.01	0.00E+00	0.00E+00
Th-230	1.48E-04	1	3.90E-02	0.01	0.00E+00	0.00E+00
Th-232	0.00E+00	1	3.90E-02	0.01	0.00E+00	0.00E+00
U-232	2.05E-02	1	3.90E-02	0.01	0.00E+00	0.00E+00
U-233	4.07E-05	1	3.90E-02	0.01	0.00E+00	0.00E+00
U-234	6.77E-01	1	3.90E-02	0.01	0.00E+00	0.00E+00
U-235	7.36E-03	1	3.90E-02	0.01	0.00E+00	0.00E+00
U-236	1.72E-01	1	3.90E-02	0.01	0.00E+00	0.00E+00
U-238	1.48E-01	1	3.90E-02	0.01	0.00E+00	0.00E+00
Zr-93	8.94E-01	1	3.90E-02	0.01	0.00E+00	0.00E+00

Category 1 Releases

Event: 1-03 SFA Drop Onto Empty Basket

Source: Average PWR

Nuclide	Source Term (Ci/FA)	# of FA's/event	Frequency (events/yr)	Mitigation Factor	Release Fraction	Annual Cat. 1 DBE Release (Ci/yr)
Co-60	2.35E+00	1	4.22E-02	0.01	0.00E+00	0.00E+00
Fe-55	4.64E+00	1	4.22E-02	0.01	0.00E+00	0.00E+00
Ac-227	1.61E-05	1	4.22E-02	0.01	0.00E+00	0.00E+00
Am-241	1.98E+03	1	4.22E-02	0.01	0.00E+00	0.00E+00
Am-242m	6.39E+00	1	4.22E-02	0.01	0.00E+00	0.00E+00
Am-243	2.20E+01	1	4.22E-02	0.01	0.00E+00	0.00E+00
C-14	3.32E-01	1	4.22E-02	0.01	0.00E+00	0.00E+00
Cd-113m	7.66E+00	1	4.22E-02	0.01	0.00E+00	0.00E+00
Cl-36	6.80E-03	1	4.22E-02	0.01	0.00E+00	0.00E+00
Cm-242	5.27E+00	1	4.22E-02	0.01	0.00E+00	0.00E+00
Cm-243	1.03E+01	1	4.22E-02	0.01	0.00E+00	0.00E+00
Cm-244	1.36E+03	1	4.22E-02	0.01	0.00E+00	0.00E+00
Cm-245	3.07E-01	1	4.22E-02	0.01	0.00E+00	0.00E+00
Cm-246	1.04E-01	1	4.22E-02	0.01	0.00E+00	0.00E+00
Co-60	3.13E+02	1	4.22E-02	0.01	0.00E+00	0.00E+00
Cs-134	2.52E+01	1	4.22E-02	0.01	0.00E+00	0.00E+00
Cs-135	3.50E-01	1	4.22E-02	0.01	0.00E+00	0.00E+00
Cs-137	4.11E+04	1	4.22E-02	0.01	0.00E+00	0.00E+00
Eu-154	6.71E+02	1	4.22E-02	0.01	0.00E+00	0.00E+00
Eu-155	5.16E+01	1	4.22E-02	0.01	0.00E+00	0.00E+00
Fe-55	3.47E+00	1	4.22E-02	0.01	0.00E+00	0.00E+00
H-3	1.14E+02	1	**4.22E-02**	**1.0**	3.00E-01	**1.44E+00**
I-129	2.20E-02	1	**4.22E-02**	**1.0**	3.00E-01	**2.78E-04**
Kr-85	1.13E+03	1	**4.22E-02**	**1.0**	3.00E-01	**1.43E+01**
Nb-93m	1.30E+01	1	4.22E-02	0.01	0.00E+00	0.00E+00
Nb-94	8.39E-01	1	4.22E-02	0.01	0.00E+00	0.00E+00
Ni-59	2.09E+00	1	4.22E-02	0.01	0.00E+00	0.00E+00
Ni-63	2.52E+02	1	4.22E-02	0.01	0.00E+00	0.00E+00
Np-237	2.47E-01	1	4.22E-02	0.01	0.00E+00	0.00E+00
Pa-231	2.97E-05	1	4.22E-02	0.01	0.00E+00	0.00E+00
Pb-210	0.00E+00	1	4.22E-02	0.01	0.00E+00	0.00E+00
Pd-107	8.41E-02	1	4.22E-02	0.01	0.00E+00	0.00E+00
Pm-147	1.19E+02	1	4.22E-02	0.01	0.00E+00	0.00E+00
Pu-238	2.29E+03	1	4.22E-02	0.01	0.00E+00	0.00E+00
Pu-239	1.77E+02	1	4.22E-02	0.01	0.00E+00	0.00E+00
Pu-240	3.18E+02	1	4.22E-02	0.01	0.00E+00	0.00E+00
Pu-241	2.47E+04	1	4.22E-02	0.01	0.00E+00	0.00E+00
Pu-242	1.64E+00	1	4.22E-02	0.01	0.00E+00	0.00E+00
Ra-226	0.00E+00	1	4.22E-02	0.01	0.00E+00	0.00E+00
Ra-228	0.00E+00	1	4.22E-02	0.01	0.00E+00	0.00E+00
Ru-106	1.23E-02	1	4.22E-02	0.01	0.00E+00	0.00E+00
Sb-125	9.71E+00	1	4.22E-02	0.01	0.00E+00	0.00E+00
Se-79	4.57E-02	1	4.22E-02	0.01	0.00E+00	0.00E+00
Sm-147	0.00E+00	1	4.22E-02	0.01	0.00E+00	0.00E+00
Sm-151	2.11E+02	1	4.22E-02	0.01	0.00E+00	0.00E+00
Sn-126	3.85E-01	1	4.22E-02	0.01	0.00E+00	0.00E+00
Sr-90	2.72E+04	1	4.22E-02	0.01	0.00E+00	0.00E+00
Tc-99	8.99E+00	1	4.22E-02	0.01	0.00E+00	0.00E+00
Th-229	0.00E+00	1	4.22E-02	0.01	0.00E+00	0.00E+00
Th-230	1.48E-04	1	4.22E-02	0.01	0.00E+00	0.00E+00
Th-232	0.00E+00	1	4.22E-02	0.01	0.00E+00	0.00E+00
U-232	2.05E-02	1	4.22E-02	0.01	0.00E+00	0.00E+00
U-233	4.07E-05	1	4.22E-02	0.01	0.00E+00	0.00E+00
U-234	6.77E-01	1	4.22E-02	0.01	0.00E+00	0.00E+00
U-235	7.36E-03	1	4.22E-02	0.01	0.00E+00	0.00E+00
U-236	1.72E-01	1	4.22E-02	0.01	0.00E+00	0.00E+00
U-238	1.48E-01	1	4.22E-02	0.01	0.00E+00	0.00E+00
Zr-93	8.94E-01	1	4.22E-02	0.01	0.00E+00	0.00E+00

Category 1 Releases

Event: 1-04 SFA Drop Onto Another SFA in Basket Staging Rack (Lowering Into)

Source: **Average PWR**

Nuclide	Source Term (Ci/FA)	# of FA's/event	Frequency (events/yr)	Mitigation Factor	Release Fraction	Annual Cat. 1 DBE Release (Ci/yr)
Co-60	1.17E+00	2	1.92E-01	0.01	0.00E+00	0.00E+00
Fe-55	4.64E+00	2	1.92E-01	0.01	0.00E+00	0.00E+00
Ac-227	1.61E-05	2	1.92E-01	0.01	0.00E+00	0.00E+00
Am-241	1.98E+03	2	1.92E-01	0.01	0.00E+00	0.00E+00
Am-242m	6.39E+00	2	1.92E-01	0.01	0.00E+00	0.00E+00
Am-243	2.20E+01	2	1.92E-01	0.01	0.00E+00	0.00E+00
C-14	3.32E-01	2	1.92E-01	0.01	0.00E+00	0.00E+00
Cd-113m	7.66E+00	2	1.92E-01	0.01	0.00E+00	0.00E+00
Cl-36	6.80E-03	2	1.92E-01	0.01	0.00E+00	0.00E+00
Cm-242	5.27E+00	2	1.92E-01	0.01	0.00E+00	0.00E+00
Cm-243	1.03E+01	2	1.92E-01	0.01	0.00E+00	0.00E+00
Cm-244	1.36E+03	2	1.92E-01	0.01	0.00E+00	0.00E+00
Cm-245	3.07E-01	2	1.92E-01	0.01	0.00E+00	0.00E+00
Cm-246	1.04E-01	2	1.92E-01	0.01	0.00E+00	0.00E+00
Co-60	3.13E+02	2	1.92E-01	0.01	0.00E+00	0.00E+00
Cs-134	2.52E+01	2	1.92E-01	0.01	0.00E+00	0.00E+00
Cs-135	3.50E-01	2	1.92E-01	0.01	0.00E+00	0.00E+00
Cs-137	4.11E+04	2	1.92E-01	0.01	0.00E+00	0.00E+00
Eu-154	6.71E+02	2	1.92E-01	0.01	0.00E+00	0.00E+00
Eu-155	5.16E+01	2	1.92E-01	0.01	0.00E+00	0.00E+00
Fe-55	3.47E+00	2	1.92E-01	0.01	0.00E+00	0.00E+00
H-3	1.14E+02	2	1.92E-01	1.0	3.00E-01	1.31E+01
I-129	2.20E-02	2	1.92E-01	1.0	3.00E-01	2.54E-03
Kr-85	1.13E+03	2	1.92E-01	1.0	3.00E-01	1.30E+02
Nb-93m	1.30E+01	2	1.92E-01	0.01	0.00E+00	0.00E+00
Nb-94	8.39E-01	2	1.92E-01	0.01	0.00E+00	0.00E+00
Ni-59	2.09E+00	2	1.92E-01	0.01	0.00E+00	0.00E+00
Ni-63	2.52E+02	2	1.92E-01	0.01	0.00E+00	0.00E+00
Np-237	2.47E-01	2	1.92E-01	0.01	0.00E+00	0.00E+00
Pa-231	2.97E-05	2	1.92E-01	0.01	0.00E+00	0.00E+00
Pb-210	0.00E+00	2	1.92E-01	0.01	0.00E+00	0.00E+00
Pd-107	8.41E-02	2	1.92E-01	0.01	0.00E+00	0.00E+00
Pm-147	1.19E+02	2	1.92E-01	0.01	0.00E+00	0.00E+00
Pu-238	2.29E+03	2	1.92E-01	0.01	0.00E+00	0.00E+00
Pu-239	1.77E+02	2	1.92E-01	0.01	0.00E+00	0.00E+00
Pu-240	3.18E+02	2	1.92E-01	0.01	0.00E+00	0.00E+00
Pu-241	2.47E+04	2	1.92E-01	0.01	0.00E+00	0.00E+00
Pu-242	1.64E+00	2	1.92E-01	0.01	0.00E+00	0.00E+00
Ra-226	0.00E+00	2	1.92E-01	0.01	0.00E+00	0.00E+00
Ra-228	0.00E+00	2	1.92E-01	0.01	0.00E+00	0.00E+00
Ru-106	1.23E-02	2	1.92E-01	0.01	0.00E+00	0.00E+00
Sb-125	9.71E+00	2	1.92E-01	0.01	0.00E+00	0.00E+00
Se-79	4.57E-02	2	1.92E-01	0.01	0.00E+00	0.00E+00
Sm-147	0.00E+00	2	1.92E-01	0.01	0.00E+00	0.00E+00
Sm-151	2.11E+02	2	1.92E-01	0.01	0.00E+00	0.00E+00
Sn-126	3.85E-01	2	1.92E-01	0.01	0.00E+00	0.00E+00
Sr-90	2.72E+04	2	1.92E-01	0.01	0.00E+00	0.00E+00
Tc-99	8.99E+00	2	1.92E-01	0.01	0.00E+00	0.00E+00
Th-229	0.00E+00	2	1.92E-01	0.01	0.00E+00	0.00E+00
Th-230	1.48E-04	2	1.92E-01	0.01	0.00E+00	0.00E+00
Th-232	0.00E+00	2	1.92E-01	0.01	0.00E+00	0.00E+00
U-232	2.05E-02	2	1.92E-01	0.01	0.00E+00	0.00E+00
U-233	4.07E-05	2	1.92E-01	0.01	0.00E+00	0.00E+00
U-234	6.77E-01	2	1.92E-01	0.01	0.00E+00	0.00E+00
U-235	7.36E-03	2	1.92E-01	0.01	0.00E+00	0.00E+00
U-236	1.72E-01	2	1.92E-01	0.01	0.00E+00	0.00E+00
U-238	1.48E-01	2	1.92E-01	0.01	0.00E+00	0.00E+00
Zr-93	8.94E-01	2	1.92E-01	0.01	0.00E+00	0.00E+00

Category 1 Releases

Event: 1-05 Basket Drop Onto Another Basket in Basket Staging Rack (Lifting Out)

Source: **Average PWR**

Nuclide	Source Term (Ci/FA)	# of FA's/event	Frequency (events/yr)	Mitigation Factor	Release Fraction	Annual Cat. 1 DBE Release (Ci/yr)
Co-60	1.17E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Fe-55	4.64E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Ac-227	1.61E-05	8	4.10E-02	0.01	0.00E+00	0.00E+00
Am-241	1.98E+03	8	4.10E-02	0.01	0.00E+00	0.00E+00
Am-242m	6.39E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Am-243	2.20E+01	8	4.10E-02	0.01	0.00E+00	0.00E+00
C-14	3.32E-01	8	4.10E-02	0.01	0.00E+00	0.00E+00
Cd-113m	7.66E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Cl-36	6.80E-03	8	4.10E-02	0.01	0.00E+00	0.00E+00
Cm-242	5.27E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Cm-243	1.03E+01	8	4.10E-02	0.01	0.00E+00	0.00E+00
Cm-244	1.36E+03	8	4.10E-02	0.01	0.00E+00	0.00E+00
Cm-245	3.07E-01	8	4.10E-02	0.01	0.00E+00	0.00E+00
Cm-246	1.04E-01	8	4.10E-02	0.01	0.00E+00	0.00E+00
Co-60	3.13E+02	8	4.10E-02	0.01	0.00E+00	0.00E+00
Cs-134	2.52E+01	8	4.10E-02	0.01	0.00E+00	0.00E+00
Cs-135	3.50E-01	8	4.10E-02	0.01	0.00E+00	0.00E+00
Cs-137	4.11E+04	8	4.10E-02	0.01	0.00E+00	0.00E+00
Eu-154	6.71E+02	8	4.10E-02	0.01	0.00E+00	0.00E+00
Eu-155	5.16E+01	8	4.10E-02	0.01	0.00E+00	0.00E+00
Fe-55	3.47E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
H-3	1.14E+02	8	**4.10E-02**	1.0	3.00E-01	1.12E+01
I-129	2.20E-02	8	**4.10E-02**	1.0	3.00E-01	2.17E-03
Kr-85	1.13E+03	8	**4.10E-02**	1.0	3.00E-01	1.11E+02
Nb-93m	1.30E+01	8	4.10E-02	0.01	0.00E+00	0.00E+00
Nb-94	8.39E-01	8	4.10E-02	0.01	0.00E+00	0.00E+00
Ni-59	2.09E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Ni-63	2.52E+02	8	4.10E-02	0.01	0.00E+00	0.00E+00
Np-237	2.47E-01	8	4.10E-02	0.01	0.00E+00	0.00E+00
Pa-231	2.97E-05	8	4.10E-02	0.01	0.00E+00	0.00E+00
Pb-210	0.00E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Pd-107	8.41E-02	8	4.10E-02	0.01	0.00E+00	0.00E+00
Pm-147	1.19E+02	8	4.10E-02	0.01	0.00E+00	0.00E+00
Pu-238	2.29E+03	8	4.10E-02	0.01	0.00E+00	0.00E+00
Pu-239	1.77E+02	8	4.10E-02	0.01	0.00E+00	0.00E+00
Pu-240	3.18E+02	8	4.10E-02	0.01	0.00E+00	0.00E+00
Pu-241	2.47E+04	8	4.10E-02	0.01	0.00E+00	0.00E+00
Pu-242	1.64E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Ra-226	0.00E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Ra-228	0.00E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Ru-106	1.23E-02	8	4.10E-02	0.01	0.00E+00	0.00E+00
Sb-125	9.71E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Se-79	4.57E-02	8	4.10E-02	0.01	0.00E+00	0.00E+00
Sm-147	0.00E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Sm-151	2.11E+02	8	4.10E-02	0.01	0.00E+00	0.00E+00
Sn-126	3.85E-01	8	4.10E-02	0.01	0.00E+00	0.00E+00
Sr-90	2.72E+04	8	4.10E-02	0.01	0.00E+00	0.00E+00
Tc-99	8.99E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Th-229	0.00E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Th-230	1.48E-04	8	4.10E-02	0.01	0.00E+00	0.00E+00
Th-232	0.00E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
U-232	2.05E-02	8	4.10E-02	0.01	0.00E+00	0.00E+00
U-233	4.07E-05	8	4.10E-02	0.01	0.00E+00	0.00E+00
U-234	6.77E-01	8	4.10E-02	0.01	0.00E+00	0.00E+00
U-235	7.36E-03	8	4.10E-02	0.01	0.00E+00	0.00E+00
U-236	1.72E-01	8	4.10E-02	0.01	0.00E+00	0.00E+00
U-238	1.48E-01	8	4.10E-02	0.01	0.00E+00	0.00E+00
Zr-93	8.94E-01	8	4.10E-02	0.01	0.00E+00	0.00E+00

Category 1 Releases

Event: 1-06 Basket Drop Onto Another Basket in Pool (Transfer Into Pool Storage)

Source: **Average PWR**

Nuclide	Source Term (Ci/FA)	# of FA's/event	Frequency (events/yr)	Mitigation Factor	Release Fraction	Annual Cat. 1 DBE Release (Ci/yr)
Co-60	1.17E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Fe-55	4.64E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Ac-227	1.61E-05	8	4.10E-02	0.01	0.00E+00	0.00E+00
Am-241	1.98E+03	8	4.10E-02	0.01	0.00E+00	0.00E+00
Am-242m	6.39E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Am-243	2.20E+01	8	4.10E-02	0.01	0.00E+00	0.00E+00
C-14	3.32E-01	8	4.10E-02	0.01	0.00E+00	0.00E+00
Cd-113m	7.66E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Cl-36	6.80E-03	8	4.10E-02	0.01	0.00E+00	0.00E+00
Cm-242	5.27E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Cm-243	1.03E+01	8	4.10E-02	0.01	0.00E+00	0.00E+00
Cm-244	1.36E+03	8	4.10E-02	0.01	0.00E+00	0.00E+00
Cm-245	3.07E-01	8	4.10E-02	0.01	0.00E+00	0.00E+00
Cm-246	1.04E-01	8	4.10E-02	0.01	0.00E+00	0.00E+00
Co-60	3.13E+02	8	4.10E-02	0.01	0.00E+00	0.00E+00
Cs-134	2.52E+01	8	4.10E-02	0.01	0.00E+00	0.00E+00
Cs-135	3.50E-01	8	4.10E-02	0.01	0.00E+00	0.00E+00
Cs-137	4.11E+04	8	4.10E-02	0.01	0.00E+00	0.00E+00
Eu-154	6.71E+02	8	4.10E-02	0.01	0.00E+00	0.00E+00
Eu-155	5.16E+01	8	4.10E-02	0.01	0.00E+00	0.00E+00
Fe-55	3.47E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
H-3	1.14E+02	8	**4.10E-02**	1.0	3.00E-01	1.12E+01
I-129	2.20E-02	8	**4.10E-02**	1.0	3.00E-01	2.17E-03
Kr-85	1.13E+03	8	**4.10E-02**	1.0	3.00E-01	1.11E+02
Nb-93m	1.30E+01	8	4.10E-02	0.01	0.00E+00	0.00E+00
Nb-94	8.39E-01	8	4.10E-02	0.01	0.00E+00	0.00E+00
Ni-59	2.09E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Ni-63	2.52E+02	8	4.10E-02	0.01	0.00E+00	0.00E+00
Np-237	2.47E-01	8	4.10E-02	0.01	0.00E+00	0.00E+00
Pa-231	2.97E-05	8	4.10E-02	0.01	0.00E+00	0.00E+00
Pb-210	0.00E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Pd-107	8.41E-02	8	4.10E-02	0.01	0.00E+00	0.00E+00
Pm-147	1.19E+02	8	4.10E-02	0.01	0.00E+00	0.00E+00
Pu-238	2.29E+03	8	4.10E-02	0.01	0.00E+00	0.00E+00
Pu-239	1.77E+02	8	4.10E-02	0.01	0.00E+00	0.00E+00
Pu-240	3.18E+02	8	4.10E-02	0.01	0.00E+00	0.00E+00
Pu-241	2.47E+04	8	4.10E-02	0.01	0.00E+00	0.00E+00
Pu-242	1.64E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Ra-226	0.00E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Ra-228	0.00E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Ru-106	1.23E-02	8	4.10E-02	0.01	0.00E+00	0.00E+00
Sb-125	9.71E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Se-79	4.57E-02	8	4.10E-02	0.01	0.00E+00	0.00E+00
Sm-147	0.00E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Sm-151	2.11E+02	8	4.10E-02	0.01	0.00E+00	0.00E+00
Sn-126	3.85E-01	8	4.10E-02	0.01	0.00E+00	0.00E+00
Sr-90	2.72E+04	8	4.10E-02	0.01	0.00E+00	0.00E+00
Tc-99	8.99E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Th-229	0.00E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Th-230	1.48E-04	8	4.10E-02	0.01	0.00E+00	0.00E+00
Th-232	0.00E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
U-232	2.05E-02	8	4.10E-02	0.01	0.00E+00	0.00E+00
U-233	4.07E-05	8	4.10E-02	0.01	0.00E+00	0.00E+00
U-234	6.77E-01	8	4.10E-02	0.01	0.00E+00	0.00E+00
U-235	7.36E-03	8	4.10E-02	0.01	0.00E+00	0.00E+00
U-236	1.72E-01	8	4.10E-02	0.01	0.00E+00	0.00E+00
U-238	1.48E-01	8	4.10E-02	0.01	0.00E+00	0.00E+00
Zr-93	8.94E-01	8	4.10E-02	0.01	0.00E+00	0.00E+00

Category 1 Releases

Event: 1-07 Basket Drop Onto Another Basket in Pool (Transfer Out of Pool Storage)

Source: Average PWR

Nuclide	Source Term (Ci/FA)	# of FA's/event	Frequency (events/yr)	Mitigation Factor	Release Fraction	Annual Cat. 1 DBE Release (Ci/yr)
Co-60	1.17E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Fe-55	4.64E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Ac-227	1.61E-05	8	4.10E-02	0.01	0.00E+00	0.00E+00
Am-241	1.98E+03	8	4.10E-02	0.01	0.00E+00	0.00E+00
Am-242m	6.39E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Am-243	2.20E+01	8	4.10E-02	0.01	0.00E+00	0.00E+00
C-14	3.32E-01	8	4.10E-02	0.01	0.00E+00	0.00E+00
Cd-113m	7.66E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Cl-36	6.80E-03	8	4.10E-02	0.01	0.00E+00	0.00E+00
Cm-242	5.27E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Cm-243	1.03E+01	8	4.10E-02	0.01	0.00E+00	0.00E+00
Cm-244	1.36E+03	8	4.10E-02	0.01	0.00E+00	0.00E+00
Cm-245	3.07E-01	8	4.10E-02	0.01	0.00E+00	0.00E+00
Cm-246	1.04E-01	8	4.10E-02	0.01	0.00E+00	0.00E+00
Co-60	3.13E+02	8	4.10E-02	0.01	0.00E+00	0.00E+00
Cs-134	2.52E+01	8	4.10E-02	0.01	0.00E+00	0.00E+00
Cs-135	3.50E-01	8	4.10E-02	0.01	0.00E+00	0.00E+00
Cs-137	4.11E+04	8	4.10E-02	0.01	0.00E+00	0.00E+00
Eu-154	6.71E+02	8	4.10E-02	0.01	0.00E+00	0.00E+00
Eu-155	5.16E+01	8	4.10E-02	0.01	0.00E+00	0.00E+00
Fe-55	3.47E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
H-3	1.14E+02	8	**4.10E-02**	**1.0**	3.00E-01	1.12E+01
I-129	2.20E-02	8	**4.10E-02**	**1.0**	3.00E-01	2.17E-03
Kr-85	1.13E+03	8	**4.10E-02**	**1.0**	3.00E-01	1.11E+02
Nb-93m	1.30E+01	8	4.10E-02	0.01	0.00E+00	0.00E+00
Nb-94	8.39E-01	8	4.10E-02	0.01	0.00E+00	0.00E+00
Ni-59	2.09E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Ni-63	2.52E+02	8	4.10E-02	0.01	0.00E+00	0.00E+00
Np-237	2.47E-01	8	4.10E-02	0.01	0.00E+00	0.00E+00
Pa-231	2.97E-05	8	4.10E-02	0.01	0.00E+00	0.00E+00
Pb-210	0.00E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Pd-107	8.41E-02	8	4.10E-02	0.01	0.00E+00	0.00E+00
Pm-147	1.19E+02	8	4.10E-02	0.01	0.00E+00	0.00E+00
Pu-238	2.29E+03	8	4.10E-02	0.01	0.00E+00	0.00E+00
Pu-239	1.77E+02	8	4.10E-02	0.01	0.00E+00	0.00E+00
Pu-240	3.18E+02	8	4.10E-02	0.01	0.00E+00	0.00E+00
Pu-241	2.47E+04	8	4.10E-02	0.01	0.00E+00	0.00E+00
Pu-242	1.64E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Ra-226	0.00E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Ra-228	0.00E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Ru-106	1.23E-02	8	4.10E-02	0.01	0.00E+00	0.00E+00
Sb-125	9.71E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Se-79	4.57E-02	8	4.10E-02	0.01	0.00E+00	0.00E+00
Sm-147	0.00E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Sm-151	2.11E+02	8	4.10E-02	0.01	0.00E+00	0.00E+00
Sn-126	3.85E-01	8	4.10E-02	0.01	0.00E+00	0.00E+00
Sr-90	2.72E+04	8	4.10E-02	0.01	0.00E+00	0.00E+00
Tc-99	8.99E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Th-229	0.00E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
Th-230	1.48E-04	8	4.10E-02	0.01	0.00E+00	0.00E+00
Th-232	0.00E+00	8	4.10E-02	0.01	0.00E+00	0.00E+00
U-232	2.05E-02	8	4.10E-02	0.01	0.00E+00	0.00E+00
U-233	4.07E-05	8	4.10E-02	0.01	0.00E+00	0.00E+00
U-234	6.77E-01	8	4.10E-02	0.01	0.00E+00	0.00E+00
U-235	7.36E-03	8	4.10E-02	0.01	0.00E+00	0.00E+00
U-236	1.72E-01	8	4.10E-02	0.01	0.00E+00	0.00E+00
U-238	1.48E-01	8	4.10E-02	0.01	0.00E+00	0.00E+00
Zr-93	8.94E-01	8	4.10E-02	0.01	0.00E+00	0.00E+00

Category 1 Releases

Event: 1-08 Basket Drop Onto Transfer Cart or Pool Floor

Source: **Average PWR**

Nuclide	Source Term (Ci/FA)	# of FA's/event	Frequency (events/yr)	Mitigation Factor	Release Fraction	Annual Cat. 1 DBE Release (Ci/yr)
Co-60	1.17E+00	4	4.10E-02	0.01	0.00E+00	0.00E+00
Fe-55	4.64E+00	4	4.10E-02	0.01	0.00E+00	0.00E+00
Ac-227	1.61E-05	4	4.10E-02	0.01	0.00E+00	0.00E+00
Am-241	1.98E+03	4	4.10E-02	0.01	0.00E+00	0.00E+00
Am-242m	6.39E+00	4	4.10E-02	0.01	0.00E+00	0.00E+00
Am-243	2.20E+01	4	4.10E-02	0.01	0.00E+00	0.00E+00
C-14	3.32E-01	4	4.10E-02	0.01	0.00E+00	0.00E+00
Cd-113m	7.66E+00	4	4.10E-02	0.01	0.00E+00	0.00E+00
Cl-36	6.80E-03	4	4.10E-02	0.01	0.00E+00	0.00E+00
Cm-242	5.27E+00	4	4.10E-02	0.01	0.00E+00	0.00E+00
Cm-243	1.03E+01	4	4.10E-02	0.01	0.00E+00	0.00E+00
Cm-244	1.36E+03	4	4.10E-02	0.01	0.00E+00	0.00E+00
Cm-245	3.07E-01	4	4.10E-02	0.01	0.00E+00	0.00E+00
Cm-246	1.04E-01	4	4.10E-02	0.01	0.00E+00	0.00E+00
Co-60	3.13E+02	4	4.10E-02	0.01	0.00E+00	0.00E+00
Cs-134	2.52E+01	4	4.10E-02	0.01	0.00E+00	0.00E+00
Cs-135	3.50E-01	4	4.10E-02	0.01	0.00E+00	0.00E+00
Cs-137	4.11E+04	4	4.10E-02	0.01	0.00E+00	0.00E+00
Eu-154	6.71E+02	4	4.10E-02	0.01	0.00E+00	0.00E+00
Eu-155	5.16E+01	4	4.10E-02	0.01	0.00E+00	0.00E+00
Fe-55	3.47E+00	4	4.10E-02	0.01	0.00E+00	0.00E+00
H-3	1.14E+02	4	4.10E-02	1.0	3.00E-01	5.61E+00
I-129	2.20E-02	4	4.10E-02	1.0	3.00E-01	1.08E-03
Kr-85	1.13E+03	4	4.10E-02	1.0	3.00E-01	5.56E+01
Nb-93m	1.30E+01	4	4.10E-02	0.01	0.00E+00	0.00E+00
Nb-94	8.39E-01	4	4.10E-02	0.01	0.00E+00	0.00E+00
Ni-59	2.09E+00	4	4.10E-02	0.01	0.00E+00	0.00E+00
Ni-63	2.52E+02	4	4.10E-02	0.01	0.00E+00	0.00E+00
Np-237	2.47E-01	4	4.10E-02	0.01	0.00E+00	0.00E+00
Pa-231	2.97E-05	4	4.10E-02	0.01	0.00E+00	0.00E+00
Pb-210	0.00E+00	4	4.10E-02	0.01	0.00E+00	0.00E+00
Pd-107	8.41E-02	4	4.10E-02	0.01	0.00E+00	0.00E+00
Pm-147	1.19E+02	4	4.10E-02	0.01	0.00E+00	0.00E+00
Pu-238	2.29E+03	4	4.10E-02	0.01	0.00E+00	0.00E+00
Pu-239	1.77E+02	4	4.10E-02	0.01	0.00E+00	0.00E+00
Pu-240	3.18E+02	4	4.10E-02	0.01	0.00E+00	0.00E+00
Pu-241	2.47E+04	4	4.10E-02	0.01	0.00E+00	0.00E+00
Pu-242	1.64E+00	4	4.10E-02	0.01	0.00E+00	0.00E+00
Ra-226	0.00E+00	4	4.10E-02	0.01	0.00E+00	0.00E+00
Ra-228	0.00E+00	4	4.10E-02	0.01	0.00E+00	0.00E+00
Ru-106	1.23E-02	4	4.10E-02	0.01	0.00E+00	0.00E+00
Sb-125	9.71E+00	4	4.10E-02	0.01	0.00E+00	0.00E+00
Se-79	4.57E-02	4	4.10E-02	0.01	0.00E+00	0.00E+00
Sm-147	0.00E+00	4	4.10E-02	0.01	0.00E+00	0.00E+00
Sm-151	2.11E+02	4	4.10E-02	0.01	0.00E+00	0.00E+00
Sn-126	3.85E-01	4	4.10E-02	0.01	0.00E+00	0.00E+00
Sr-90	2.72E+04	4	4.10E-02	0.01	0.00E+00	0.00E+00
Tc-99	8.99E+00	4	4.10E-02	0.01	0.00E+00	0.00E+00
Th-229	0.00E+00	4	4.10E-02	0.01	0.00E+00	0.00E+00
Th-230	1.48E-04	4	4.10E-02	0.01	0.00E+00	0.00E+00
Th-232	0.00E+00	4	4.10E-02	0.01	0.00E+00	0.00E+00
U-232	2.05E-02	4	4.10E-02	0.01	0.00E+00	0.00E+00
U-233	4.07E-05	4	4.10E-02	0.01	0.00E+00	0.00E+00
U-234	6.77E-01	4	4.10E-02	0.01	0.00E+00	0.00E+00
U-235	7.36E-03	4	4.10E-02	0.01	0.00E+00	0.00E+00
U-236	1.72E-01	4	4.10E-02	0.01	0.00E+00	0.00E+00
U-238	1.48E-01	4	4.10E-02	0.01	0.00E+00	0.00E+00
Zr-93	8.94E-01	4	4.10E-02	0.01	0.00E+00	0.00E+00

Category 1 Releases

Event: 1-09 Basket Drop Back Into Pool

Source: Average PWR

Nuclide	Source Term (Ci/FA)	# of FA's/event	Frequency (events/yr)	Mitigation Factor	Release Fraction	Annual Cat. 1 DBE Release (Ci/yr)
Co-60	1.17E+00	4	4.10E-02	0.01	0.00E+00	0.00E+00
Fe-55	4.64E+00	4	4.10E-02	0.01	0.00E+00	0.00E+00
Ac-227	1.61E-05	4	4.10E-02	0.01	0.00E+00	0.00E+00
Am-241	1.98E+03	4	4.10E-02	0.01	0.00E+00	0.00E+00
Am-242m	6.39E+00	4	4.10E-02	0.01	0.00E+00	0.00E+00
Am-243	2.20E+01	4	4.10E-02	0.01	0.00E+00	0.00E+00
C-14	3.32E-01	4	4.10E-02	0.01	0.00E+00	0.00E+00
Cd-113m	7.66E+00	4	4.10E-02	0.01	0.00E+00	0.00E+00
Cl-36	6.80E-03	4	4.10E-02	0.01	0.00E+00	0.00E+00
Cm-242	5.27E+00	4	4.10E-02	0.01	0.00E+00	0.00E+00
Cm-243	1.03E+01	4	4.10E-02	0.01	0.00E+00	0.00E+00
Cm-244	1.36E+03	4	4.10E-02	0.01	0.00E+00	0.00E+00
Cm-245	3.07E-01	4	4.10E-02	0.01	0.00E+00	0.00E+00
Cm-246	1.04E-01	4	4.10E-02	0.01	0.00E+00	0.00E+00
Co-60	3.13E+02	4	4.10E-02	0.01	0.00E+00	0.00E+00
Cs-134	2.52E+01	4	4.10E-02	0.01	0.00E+00	0.00E+00
Cs-135	3.50E-01	4	4.10E-02	0.01	0.00E+00	0.00E+00
Cs-137	4.11E+04	4	4.10E-02	0.01	0.00E+00	0.00E+00
Eu-154	6.71E+02	4	4.10E-02	0.01	0.00E+00	0.00E+00
Eu-155	5.16E+01	4	4.10E-02	0.01	0.00E+00	0.00E+00
Fe-55	3.47E+00	4	4.10E-02	0.01	0.00E+00	0.00E+00
H-3	1.14E+02	4	**4.10E-02**	**1.0**	3.00E-01	5.61E+00
I-129	2.20E-02	4	**4.10E-02**	**1.0**	3.00E-01	1.08E-03
Kr-85	1.13E+03	4	**4.10E-02**	**1.0**	3.00E-01	5.56E+01
Nb-93m	1.30E+01	4	4.10E-02	0.01	0.00E+00	0.00E+00
Nb-94	8.39E-01	4	4.10E-02	0.01	0.00E+00	0.00E+00
Ni-59	2.09E+00	4	4.10E-02	0.01	0.00E+00	0.00E+00
Ni-63	2.52E+02	4	4.10E-02	0.01	0.00E+00	0.00E+00
Np-237	2.47E-01	4	4.10E-02	0.01	0.00E+00	0.00E+00
Pa-231	2.97E-05	4	4.10E-02	0.01	0.00E+00	0.00E+00
Pb-210	0.00E+00	4	4.10E-02	0.01	0.00E+00	0.00E+00
Pd-107	8.41E-02	4	4.10E-02	0.01	0.00E+00	0.00E+00
Pm-147	1.19E+02	4	4.10E-02	0.01	0.00E+00	0.00E+00
Pu-238	2.29E+03	4	4.10E-02	0.01	0.00E+00	0.00E+00
Pu-239	1.77E+02	4	4.10E-02	0.01	0.00E+00	0.00E+00
Pu-240	3.18E+02	4	4.10E-02	0.01	0.00E+00	0.00E+00
Pu-241	2.47E+04	4	4.10E-02	0.01	0.00E+00	0.00E+00
Pu-242	1.64E+00	4	4.10E-02	0.01	0.00E+00	0.00E+00
Ra-226	0.00E+00	4	4.10E-02	0.01	0.00E+00	0.00E+00
Ra-228	0.00E+00	4	4.10E-02	0.01	0.00E+00	0.00E+00
Ru-106	1.23E-02	4	4.10E-02	0.01	0.00E+00	0.00E+00
Sb-125	9.71E+00	4	4.10E-02	0.01	0.00E+00	0.00E+00
Se-79	4.57E-02	4	4.10E-02	0.01	0.00E+00	0.00E+00
Sm-147	0.00E+00	4	4.10E-02	0.01	0.00E+00	0.00E+00
Sm-151	2.11E+02	4	4.10E-02	0.01	0.00E+00	0.00E+00
Sn-126	3.85E-01	4	4.10E-02	0.01	0.00E+00	0.00E+00
Sr-90	2.72E+04	4	4.10E-02	0.01	0.00E+00	0.00E+00
Tc-99	8.99E+00	4	4.10E-02	0.01	0.00E+00	0.00E+00
Th-229	0.00E+00	4	4.10E-02	0.01	0.00E+00	0.00E+00
Th-230	1.48E-04	4	4.10E-02	0.01	0.00E+00	0.00E+00
Th-232	0.00E+00	4	4.10E-02	0.01	0.00E+00	0.00E+00
U-232	2.05E-02	4	4.10E-02	0.01	0.00E+00	0.00E+00
U-233	4.07E-05	4	4.10E-02	0.01	0.00E+00	0.00E+00
U-234	6.77E-01	4	4.10E-02	0.01	0.00E+00	0.00E+00
U-235	7.36E-03	4	4.10E-02	0.01	0.00E+00	0.00E+00
U-236	1.72E-01	4	4.10E-02	0.01	0.00E+00	0.00E+00
U-238	1.48E-01	4	4.10E-02	0.01	0.00E+00	0.00E+00
Zr-93	8.94E-01	4	4.10E-02	0.01	0.00E+00	0.00E+00

Category 1 Releases

Event: 1-10 Basket Drop Onto ATS Hot Cell Floor

Source: Average PWR

Nuclide	Source Term (Ci/FA)	# of FA's/event	Frequency (events/yr)	Mitigation Factor	Release Fraction	Annual Cat. 1 DBE Release (Ci/yr)
Co-60	1.17E+00	4	4.10E-02	0.01	1.00E+00	1.93E-03
Fe-55	4.64E+00	4	4.10E-02	0.01	1.00E+00	7.61E-03
Ac-227	1.61E-05	4	4.10E-02	0.01	3.00E-05	7.92E-13
Am-241	1.98E+03	4	4.10E-02	0.01	3.00E-05	9.74E-05
Am-242m	6.39E+00	4	4.10E-02	0.01	3.00E-05	3.14E-07
Am-243	2.20E+01	4	4.10E-02	0.01	3.00E-05	1.08E-06
C-14	3.32E-01	4	4.10E-02	0.01	3.00E-05	1.63E-08
Cd-113m	7.66E+00	4	4.10E-02	0.01	3.00E-05	3.77E-07
Cl-36	6.80E-03	4	4.10E-02	0.01	3.00E-05	3.35E-10
Cm-242	5.27E+00	4	4.10E-02	0.01	3.00E-05	2.59E-07
Cm-243	1.03E+01	4	4.10E-02	0.01	3.00E-05	5.07E-07
Cm-244	1.36E+03	4	4.10E-02	0.01	3.00E-05	6.69E-05
Cm-245	3.07E-01	4	4.10E-02	0.01	3.00E-05	1.51E-08
Cm-246	1.04E-01	4	4.10E-02	0.01	3.00E-05	5.12E-09
Co-60	3.13E+02	4	4.10E-02	0.01	3.00E-05	1.54E-05
Cs-134	2.52E+01	4	4.10E-02	0.01	2.00E-04	8.27E-06
Cs-135	3.50E-01	4	4.10E-02	0.01	2.00E-04	1.15E-07
Cs-137	4.11E+04	4	4.10E-02	0.01	2.00E-04	1.35E-02
Eu-154	6.71E+02	4	4.10E-02	0.01	3.00E-05	3.30E-05
Eu-155	5.16E+01	4	4.10E-02	0.01	3.00E-05	2.54E-06
Fe-55	3.47E+00	4	4.10E-02	0.01	3.00E-05	1.71E-07
H-3	1.14E+02	4	4.10E-02	1.0	3.00E-01	5.61E+00
I-129	2.20E-02	4	4.10E-02	1.0	3.00E-01	1.08E-03
Kr-85	1.13E+03	4	4.10E-02	1.0	3.00E-01	5.56E+01
Nb-93m	1.30E+01	4	4.10E-02	0.01	3.00E-05	6.40E-07
Nb-94	8.39E-01	4	4.10E-02	0.01	3.00E-05	4.13E-08
Ni-59	2.09E+00	4	4.10E-02	0.01	3.00E-05	1.03E-07
Ni-63	2.52E+02	4	4.10E-02	0.01	3.00E-05	1.24E-05
Np-237	2.47E-01	4	4.10E-02	0.01	3.00E-05	1.22E-08
Pa-231	2.97E-05	4	4.10E-02	0.01	3.00E-05	1.46E-12
Pb-210	0.00E+00	4	4.10E-02	0.01	3.00E-05	0.00E+00
Pd-107	8.41E-02	4	4.10E-02	0.01	3.00E-05	4.14E-09
Pm-147	1.19E+02	4	4.10E-02	0.01	3.00E-05	5.86E-06
Pu-238	2.29E+03	4	4.10E-02	0.01	3.00E-05	1.13E-04
Pu-239	1.77E+02	4	4.10E-02	0.01	3.00E-05	8.71E-06
Pu-240	3.18E+02	4	4.10E-02	0.01	3.00E-05	1.56E-05
Pu-241	2.47E+04	4	4.10E-02	0.01	3.00E-05	1.22E-03
Pu-242	1.64E+00	4	4.10E-02	0.01	3.00E-05	8.07E-08
Ra-226	0.00E+00	4	4.10E-02	0.01	3.00E-05	0.00E+00
Ra-228	0.00E+00	4	4.10E-02	0.01	3.00E-05	0.00E+00
Ru-106	1.23E-02	4	4.10E-02	0.01	3.00E-05	6.05E-10
Sb-125	9.71E+00	4	4.10E-02	0.01	3.00E-05	4.78E-07
Se-79	4.57E-02	4	4.10E-02	0.01	3.00E-05	2.25E-09
Sm-147	0.00E+00	4	4.10E-02	0.01	3.00E-05	0.00E+00
Sm-151	2.11E+02	4	4.10E-02	0.01	3.00E-05	1.04E-05
Sn-126	3.85E-01	4	4.10E-02	0.01	3.00E-05	1.89E-08
Sr-90	2.72E+04	4	4.10E-02	0.01	3.00E-05	1.34E-03
Tc-99	8.99E+00	4	4.10E-02	0.01	3.00E-05	4.42E-07
Th-229	0.00E+00	4	4.10E-02	0.01	3.00E-05	0.00E+00
Th-230	1.48E-04	4	4.10E-02	0.01	3.00E-05	7.28E-12
Th-232	0.00E+00	4	4.10E-02	0.01	3.00E-05	0.00E+00
U-232	2.05E-02	4	4.10E-02	0.01	3.00E-05	1.01E-09
U-233	4.07E-05	4	4.10E-02	0.01	3.00E-05	2.00E-12
U-234	6.77E-01	4	4.10E-02	0.01	3.00E-05	3.33E-08
U-235	7.36E-03	4	4.10E-02	0.01	3.00E-05	3.62E-10
U-236	1.72E-01	4	4.10E-02	0.01	3.00E-05	8.46E-09
U-238	1.48E-01	4	4.10E-02	0.01	3.00E-05	7.28E-09
Zr-93	8.94E-01	4	4.10E-02	0.01	3.00E-05	4.40E-08

Category 1 Releases

Event: 1-11 Basket Drop Onto Another Basket in Dryer

Source: **Average PWR**

Nuclide	Source Term (Ci/FA)	# of FA's/event	Frequency (events/yr)	Mitigation Factor	Release Fraction	Annual Cat. 1 DBE Release (Ci/yr)
Co-60	1.17E+00	8	4.10E-02	0.01	1.00E+00	3.85E-03
Fe-55	4.64E+00	8	4.10E-02	0.01	1.00E+00	1.52E-02
Ac-227	1.61E-05	8	4.10E-02	0.01	3.00E-05	1.58E-12
Am-241	1.98E+03	8	4.10E-02	0.01	3.00E-05	1.95E-04
Am-242m	6.39E+00	8	4.10E-02	0.01	3.00E-05	6.29E-07
Am-243	2.20E+01	8	4.10E-02	0.01	3.00E-05	2.17E-06
C-14	3.32E-01	8	4.10E-02	0.01	3.00E-05	3.27E-08
Cd-113m	7.66E+00	8	4.10E-02	0.01	3.00E-05	7.54E-07
Cl-36	6.80E-03	8	4.10E-02	0.01	3.00E-05	6.69E-10
Cm-242	5.27E+00	8	4.10E-02	0.01	3.00E-05	5.19E-07
Cm-243	1.03E+01	8	4.10E-02	0.01	3.00E-05	1.01E-06
Cm-244	1.36E+03	8	4.10E-02	0.01	3.00E-05	1.34E-04
Cm-245	3.07E-01	8	4.10E-02	0.01	3.00E-05	3.02E-08
Cm-246	1.04E-01	8	4.10E-02	0.01	3.00E-05	1.02E-08
Co-60	3.13E+02	8	4.10E-02	0.01	3.00E-05	3.08E-05
Cs-134	2.52E+01	8	4.10E-02	0.01	2.00E-04	1.65E-05
Cs-135	3.50E-01	8	4.10E-02	0.01	2.00E-04	2.30E-07
Cs-137	4.11E+04	8	4.10E-02	0.01	2.00E-04	2.70E-02
Eu-154	6.71E+02	8	4.10E-02	0.01	3.00E-05	6.60E-05
Eu-155	5.16E+01	8	4.10E-02	0.01	3.00E-05	5.08E-06
Fe-55	3.47E+00	8	4.10E-02	0.01	3.00E-05	3.42E-07
H-3	1.14E+02	8	**4.10E-02**	1.0	3.00E-01	1.12E+01
I-129	2.20E-02	8	**4.10E-02**	1.0	3.00E-01	2.17E-03
Kr-85	1.13E+03	8	**4.10E-02**	1.0	3.00E-01	1.11E+02
Nb-93m	1.30E+01	8	4.10E-02	0.01	3.00E-05	1.28E-06
Nb-94	8.39E-01	8	4.10E-02	0.01	3.00E-05	8.26E-08
Ni-59	2.09E+00	8	4.10E-02	0.01	3.00E-05	2.06E-07
Ni-63	2.52E+02	8	4.10E-02	0.01	3.00E-05	2.48E-05
Np-237	2.47E-01	8	4.10E-02	0.01	3.00E-05	2.43E-08
Pa-231	2.97E-05	8	4.10E-02	0.01	3.00E-05	2.92E-12
Pb-210	0.00E+00	8	4.10E-02	0.01	3.00E-05	0.00E+00
Pd-107	8.41E-02	8	4.10E-02	0.01	3.00E-05	8.28E-09
Pm-147	1.19E+02	8	4.10E-02	0.01	3.00E-05	1.17E-05
Pu-238	2.29E+03	8	4.10E-02	0.01	3.00E-05	2.25E-04
Pu-239	1.77E+02	8	4.10E-02	0.01	3.00E-05	1.74E-05
Pu-240	3.18E+02	8	4.10E-02	0.01	3.00E-05	3.13E-05
Pu-241	2.47E+04	8	4.10E-02	0.01	3.00E-05	2.43E-03
Pu-242	1.64E+00	8	4.10E-02	0.01	3.00E-05	1.61E-07
Ra-226	0.00E+00	8	4.10E-02	0.01	3.00E-05	0.00E+00
Ra-228	0.00E+00	8	4.10E-02	0.01	3.00E-05	0.00E+00
Ru-106	1.23E-02	8	4.10E-02	0.01	3.00E-05	1.21E-09
Sb-125	9.71E+00	8	4.10E-02	0.01	3.00E-05	9.56E-07
Se-79	4.57E-02	8	4.10E-02	0.01	3.00E-05	4.50E-09
Sm-147	0.00E+00	8	4.10E-02	0.01	3.00E-05	0.00E+00
Sm-151	2.11E+02	8	4.10E-02	0.01	3.00E-05	2.08E-05
Sn-126	3.85E-01	8	4.10E-02	0.01	3.00E-05	3.79E-08
Sr-90	2.72E+04	8	4.10E-02	0.01	3.00E-05	2.68E-03
Tc-99	8.99E+00	8	4.10E-02	0.01	3.00E-05	8.85E-07
Th-229	0.00E+00	8	4.10E-02	0.01	3.00E-05	0.00E+00
Th-230	1.48E-04	8	4.10E-02	0.01	3.00E-05	1.46E-11
Th-232	0.00E+00	8	4.10E-02	0.01	3.00E-05	0.00E+00
U-232	2.05E-02	8	4.10E-02	0.01	3.00E-05	2.02E-09
U-233	4.07E-05	8	4.10E-02	0.01	3.00E-05	4.01E-12
U-234	6.77E-01	8	4.10E-02	0.01	3.00E-05	6.66E-08
U-235	7.36E-03	8	4.10E-02	0.01	3.00E-05	7.24E-10
U-236	1.72E-01	8	4.10E-02	0.01	3.00E-05	1.69E-08
U-238	1.48E-01	8	4.10E-02	0.01	3.00E-05	1.46E-08
Zr-93	8.94E-01	8	4.10E-02	0.01	3.00E-05	8.80E-08

Category 1 Releases

Event: 1-12 SFA Drop Onto Another SFA in Dryer

Source: **Average PWR**

Nuclide	Source Term (Ci/FA)	# of FA's/event	Frequency (events/yr)	Mitigation Factor	Release Fraction	Annual Cat. 1 DBE Release (Ci/yr)
Co-60	1.17E+00	2	2.34E-01	0.01	1.00E+00	5.50E-03
Fe-55	4.64E+00	2	2.34E-01	0.01	1.00E+00	2.17E-02
Ac-227	1.61E-05	2	2.34E-01	0.01	3.00E-05	2.26E-12
Am-241	1.98E+03	2	2.34E-01	0.01	3.00E-05	2.78E-04
Am-242m	6.39E+00	2	2.34E-01	0.01	3.00E-05	8.98E-07
Am-243	2.20E+01	2	2.34E-01	0.01	3.00E-05	3.09E-06
C-14	3.32E-01	2	2.34E-01	0.01	3.00E-05	4.67E-08
Cd-113m	7.66E+00	2	2.34E-01	0.01	3.00E-05	1.08E-06
Cl-36	6.80E-03	2	2.34E-01	0.01	3.00E-05	9.56E-10
Cm-242	5.27E+00	2	2.34E-01	0.01	3.00E-05	7.41E-07
Cm-243	1.03E+01	2	2.34E-01	0.01	3.00E-05	1.45E-06
Cm-244	1.36E+03	2	2.34E-01	0.01	3.00E-05	1.91E-04
Cm-245	3.07E-01	2	2.34E-01	0.01	3.00E-05	4.31E-08
Cm-246	1.04E-01	2	2.34E-01	0.01	3.00E-05	1.46E-08
Co-60	3.13E+02	2	2.34E-01	0.01	3.00E-05	4.40E-05
Cs-134	2.52E+01	2	2.34E-01	0.01	2.00E-04	2.36E-05
Cs-135	3.50E-01	2	2.34E-01	0.01	2.00E-04	3.28E-07
Cs-137	4.11E+04	2	2.34E-01	0.01	2.00E-04	3.85E-02
Eu-154	6.71E+02	2	2.34E-01	0.01	3.00E-05	9.43E-05
Eu-155	5.16E+01	2	2.34E-01	0.01	3.00E-05	7.25E-06
Fe-55	3.47E+00	2	2.34E-01	0.01	3.00E-05	4.88E-07
H-3	1.14E+02	2	**2.34E-01**	1.0	3.00E-01	1.60E+01
I-129	2.20E-02	2	**2.34E-01**	1.0	3.00E-01	3.09E-03
Kr-85	1.13E+03	2	**2.34E-01**	1.0	3.00E-01	1.59E+02
Nb-93m	1.30E+01	2	2.34E-01	0.01	3.00E-05	1.83E-06
Nb-94	8.39E-01	2	2.34E-01	0.01	3.00E-05	1.18E-07
Ni-59	2.09E+00	2	2.34E-01	0.01	3.00E-05	2.94E-07
Ni-63	2.52E+02	2	2.34E-01	0.01	3.00E-05	3.54E-05
Np-237	2.47E-01	2	2.34E-01	0.01	3.00E-05	3.47E-08
Pa-231	2.97E-05	2	2.34E-01	0.01	3.00E-05	4.17E-12
Pb-210	0.00E+00	2	2.34E-01	0.01	3.00E-05	0.00E+00
Pd-107	8.41E-02	2	2.34E-01	0.01	3.00E-05	1.18E-08
Pm-147	1.19E+02	2	2.34E-01	0.01	3.00E-05	1.67E-05
Pu-238	2.29E+03	2	2.34E-01	0.01	3.00E-05	3.22E-04
Pu-239	1.77E+02	2	2.34E-01	0.01	3.00E-05	2.49E-05
Pu-240	3.18E+02	2	2.34E-01	0.01	3.00E-05	4.47E-05
Pu-241	2.47E+04	2	2.34E-01	0.01	3.00E-05	3.47E-03
Pu-242	1.64E+00	2	2.34E-01	0.01	3.00E-05	2.30E-07
Ra-226	0.00E+00	2	2.34E-01	0.01	3.00E-05	0.00E+00
Ra-228	0.00E+00	2	2.34E-01	0.01	3.00E-05	0.00E+00
Ru-106	1.23E-02	2	2.34E-01	0.01	3.00E-05	1.73E-09
Sb-125	9.71E+00	2	2.34E-01	0.01	3.00E-05	1.36E-06
Se-79	4.57E-02	2	2.34E-01	0.01	3.00E-05	6.42E-09
Sm-147	0.00E+00	2	2.34E-01	0.01	3.00E-05	0.00E+00
Sm-151	2.11E+02	2	2.34E-01	0.01	3.00E-05	2.97E-05
Sn-126	3.85E-01	2	2.34E-01	0.01	3.00E-05	5.41E-08
Sr-90	2.72E+04	2	2.34E-01	0.01	3.00E-05	3.82E-03
Tc-99	8.99E+00	2	2.34E-01	0.01	3.00E-05	1.26E-06
Th-229	0.00E+00	2	2.34E-01	0.01	3.00E-05	0.00E+00
Th-230	1.48E-04	2	2.34E-01	0.01	3.00E-05	2.08E-11
Th-232	0.00E+00	2	2.34E-01	0.01	3.00E-05	0.00E+00
U-232	2.05E-02	2	2.34E-01	0.01	3.00E-05	2.88E-09
U-233	4.07E-05	2	2.34E-01	0.01	3.00E-05	5.72E-12
U-234	6.77E-01	2	2.34E-01	0.01	3.00E-05	9.51E-08
U-235	7.36E-03	2	2.34E-01	0.01	3.00E-05	1.03E-09
U-236	1.72E-01	2	2.34E-01	0.01	3.00E-05	2.42E-08
U-238	1.48E-01	2	2.34E-01	0.01	3.00E-05	2.08E-08
Zr-93	8.94E-01	2	2.34E-01	0.01	3.00E-05	1.26E-07

Category 1 Releases

Event: 1-13 SFA Drop Onto ATS Hot Cell Floor

Source: **Average PWR**

Nuclide	Source Term (Ci/FA)	# of FA's/event	Frequency (events/yr)	Mitigation Factor	Release Fraction	Annual Cat. 1 DBE Release (Ci/yr)
Co-60	2.35E+00	1	2.34E-01	0.01	1.00E+00	5.50E-03
Fe-55	4.64E+00	1	2.34E-01	0.01	1.00E+00	1.09E-02
Ac-227	1.61E-05	1	2.34E-01	0.01	3.00E-05	1.13E-12
Am-241	1.98E+03	1	2.34E-01	0.01	3.00E-05	1.39E-04
Am-242m	6.39E+00	1	2.34E-01	0.01	3.00E-05	4.49E-07
Am-243	2.20E+01	1	2.34E-01	0.01	3.00E-05	1.55E-06
C-14	3.32E-01	1	2.34E-01	0.01	3.00E-05	2.33E-08
Cd-113m	7.66E+00	1	2.34E-01	0.01	3.00E-05	5.38E-07
Cl-36	6.80E-03	1	2.34E-01	0.01	3.00E-05	4.78E-10
Cm-242	5.27E+00	1	2.34E-01	0.01	3.00E-05	3.70E-07
Cm-243	1.03E+01	1	2.34E-01	0.01	3.00E-05	7.24E-07
Cm-244	1.36E+03	1	2.34E-01	0.01	3.00E-05	9.56E-05
Cm-245	3.07E-01	1	2.34E-01	0.01	3.00E-05	2.16E-08
Cm-246	1.04E-01	1	2.34E-01	0.01	3.00E-05	7.31E-09
Co-60	3.13E+02	1	2.34E-01	0.01	3.00E-05	2.20E-05
Cs-134	2.52E+01	1	2.34E-01	0.01	2.00E-04	1.18E-05
Cs-135	3.50E-01	1	2.34E-01	0.01	2.00E-04	1.64E-07
Cs-137	4.11E+04	1	2.34E-01	0.01	2.00E-04	1.93E-02
Eu-154	6.71E+02	1	2.34E-01	0.01	3.00E-05	4.72E-05
Eu-155	5.16E+01	1	2.34E-01	0.01	3.00E-05	3.63E-06
Fe-55	3.47E+00	1	2.34E-01	0.01	3.00E-05	2.44E-07
H-3	1.14E+02	1	**2.34E-01**	1.0	3.00E-01	8.01E+00
I-129	2.20E-02	1	**2.34E-01**	1.0	3.00E-01	1.55E-03
Kr-85	1.13E+03	1	**2.34E-01**	1.0	3.00E-01	7.94E+01
Nb-93m	1.30E+01	1	2.34E-01	0.01	3.00E-05	9.14E-07
Nb-94	8.39E-01	1	2.34E-01	0.01	3.00E-05	5.90E-08
Ni-59	2.09E+00	1	2.34E-01	0.01	3.00E-05	1.47E-07
Ni-63	2.52E+02	1	2.34E-01	0.01	3.00E-05	1.77E-05
Np-237	2.47E-01	1	2.34E-01	0.01	3.00E-05	1.74E-08
Pa-231	2.97E-05	1	2.34E-01	0.01	3.00E-05	2.09E-12
Pb-210	0.00E+00	1	2.34E-01	0.01	3.00E-05	0.00E+00
Pd-107	8.41E-02	1	2.34E-01	0.01	3.00E-05	5.91E-09
Pm-147	1.19E+02	1	2.34E-01	0.01	3.00E-05	8.36E-06
Pu-238	2.29E+03	1	2.34E-01	0.01	3.00E-05	1.61E-04
Pu-239	1.77E+02	1	2.34E-01	0.01	3.00E-05	1.24E-05
Pu-240	3.18E+02	1	2.34E-01	0.01	3.00E-05	2.23E-05
Pu-241	2.47E+04	1	2.34E-01	0.01	3.00E-05	1.74E-03
Pu-242	1.64E+00	1	2.34E-01	0.01	3.00E-05	1.15E-07
Ra-226	0.00E+00	1	2.34E-01	0.01	3.00E-05	0.00E+00
Ra-228	0.00E+00	1	2.34E-01	0.01	3.00E-05	0.00E+00
Ru-106	1.23E-02	1	2.34E-01	0.01	3.00E-05	8.64E-10
Sb-125	9.71E+00	1	2.34E-01	0.01	3.00E-05	6.82E-07
Se-79	4.57E-02	1	2.34E-01	0.01	3.00E-05	3.21E-09
Sm-147	0.00E+00	1	2.34E-01	0.01	3.00E-05	0.00E+00
Sm-151	2.11E+02	1	2.34E-01	0.01	3.00E-05	1.48E-05
Sn-126	3.85E-01	1	2.34E-01	0.01	3.00E-05	2.71E-08
Sr-90	2.72E+04	1	2.34E-01	0.01	3.00E-05	1.91E-03
Tc-99	8.99E+00	1	2.34E-01	0.01	3.00E-05	6.32E-07
Th-229	0.00E+00	1	2.34E-01	0.01	3.00E-05	0.00E+00
Th-230	1.48E-04	1	2.34E-01	0.01	3.00E-05	1.04E-11
Th-232	0.00E+00	1	2.34E-01	0.01	3.00E-05	0.00E+00
U-232	2.05E-02	1	2.34E-01	0.01	3.00E-05	1.44E-09
U-233	4.07E-05	1	2.34E-01	0.01	3.00E-05	2.86E-12
U-234	6.77E-01	1	2.34E-01	0.01	3.00E-05	4.76E-08
U-235	7.36E-03	1	2.34E-01	0.01	3.00E-05	5.17E-10
U-236	1.72E-01	1	2.34E-01	0.01	3.00E-05	1.21E-08
U-238	1.48E-01	1	2.34E-01	0.01	3.00E-05	1.04E-08
Zr-93	8.94E-01	1	2.34E-01	0.01	3.00E-05	6.28E-08

Category 1 Releases

Event: 1-14 SFA Drop Onto Another SFA in DC

Source: **Average PWR**

Nuclide	Source Term (Ci/FA)	# of FA's/event	Frequency (events/yr)	Mitigation Factor	Release Fraction	Annual Cat. 1 DBE Release (Ci/yr)
Co-60	1.17E+00	2	2.34E-01	0.01	1.00E+00	5.50E-03
Fe-55	4.64E+00	2	2.34E-01	0.01	1.00E+00	2.17E-02
Ac-227	1.61E-05	2	2.34E-01	0.01	3.00E-05	2.26E-12
Am-241	1.98E+03	2	2.34E-01	0.01	3.00E-05	2.78E-04
Am-242m	6.39E+00	2	2.34E-01	0.01	3.00E-05	8.98E-07
Am-243	2.20E+01	2	2.34E-01	0.01	3.00E-05	3.09E-06
C-14	3.32E-01	2	2.34E-01	0.01	3.00E-05	4.67E-08
Cd-113m	7.66E+00	2	2.34E-01	0.01	3.00E-05	1.08E-06
Cl-36	6.80E-03	2	2.34E-01	0.01	3.00E-05	9.56E-10
Cm-242	5.27E+00	2	2.34E-01	0.01	3.00E-05	7.41E-07
Cm-243	1.03E+01	2	2.34E-01	0.01	3.00E-05	1.45E-06
Cm-244	1.36E+03	2	2.34E-01	0.01	3.00E-05	1.91E-04
Cm-245	3.07E-01	2	2.34E-01	0.01	3.00E-05	4.31E-08
Cm-246	1.04E-01	2	2.34E-01	0.01	3.00E-05	1.46E-08
Co-60	3.13E+02	2	2.34E-01	0.01	3.00E-05	4.40E-05
Cs-134	2.52E+01	2	2.34E-01	0.01	2.00E-04	2.36E-05
Cs-135	3.50E-01	2	2.34E-01	0.01	2.00E-04	3.28E-07
Cs-137	4.11E+04	2	2.34E-01	0.01	2.00E-04	3.85E-02
Eu-154	6.71E+02	2	2.34E-01	0.01	3.00E-05	9.43E-05
Eu-155	5.16E+01	2	2.34E-01	0.01	3.00E-05	7.25E-06
Fe-55	3.47E+00	2	2.34E-01	0.01	3.00E-05	4.88E-07
H-3	1.14E+02	2	**2.34E-01**	1.0	3.00E-01	1.60E+01
I-129	2.20E-02	2	**2.34E-01**	1.0	3.00E-01	3.09E-03
Kr-85	1.13E+03	2	**2.34E-01**	1.0	3.00E-01	1.59E+02
Nb-93m	1.30E+01	2	2.34E-01	0.01	3.00E-05	1.83E-06
Nb-94	8.39E-01	2	2.34E-01	0.01	3.00E-05	1.18E-07
Ni-59	2.09E+00	2	2.34E-01	0.01	3.00E-05	2.94E-07
Ni-63	2.52E+02	2	2.34E-01	0.01	3.00E-05	3.54E-05
Np-237	2.47E-01	2	2.34E-01	0.01	3.00E-05	3.47E-08
Pa-231	2.97E-05	2	2.34E-01	0.01	3.00E-05	4.17E-12
Pb-210	0.00E+00	2	2.34E-01	0.01	3.00E-05	0.00E+00
Pd-107	8.41E-02	2	2.34E-01	0.01	3.00E-05	1.18E-08
Pm-147	1.19E+02	2	2.34E-01	0.01	3.00E-05	1.67E-05
Pu-238	2.29E+03	2	2.34E-01	0.01	3.00E-05	3.22E-04
Pu-239	1.77E+02	2	2.34E-01	0.01	3.00E-05	2.49E-05
Pu-240	3.18E+02	2	2.34E-01	0.01	3.00E-05	4.47E-05
Pu-241	2.47E+04	2	2.34E-01	0.01	3.00E-05	3.47E-03
Pu-242	1.64E+00	2	2.34E-01	0.01	3.00E-05	2.30E-07
Ra-226	0.00E+00	2	2.34E-01	0.01	3.00E-05	0.00E+00
Ra-228	0.00E+00	2	2.34E-01	0.01	3.00E-05	0.00E+00
Ru-106	1.23E-02	2	2.34E-01	0.01	3.00E-05	1.73E-09
Sb-125	9.71E+00	2	2.34E-01	0.01	3.00E-05	1.36E-06
Se-79	4.57E-02	2	2.34E-01	0.01	3.00E-05	6.42E-09
Sm-147	0.00E+00	2	2.34E-01	0.01	3.00E-05	0.00E+00
Sm-151	2.11E+02	2	2.34E-01	0.01	3.00E-05	2.97E-05
Sn-126	3.85E-01	2	2.34E-01	0.01	3.00E-05	5.41E-08
Sr-90	2.72E+04	2	2.34E-01	0.01	3.00E-05	3.82E-03
Tc-99	8.99E+00	2	2.34E-01	0.01	3.00E-05	1.26E-06
Th-229	0.00E+00	2	2.34E-01	0.01	3.00E-05	0.00E+00
Th-230	1.48E-04	2	2.34E-01	0.01	3.00E-05	2.08E-11
Th-232	0.00E+00	2	2.34E-01	0.01	3.00E-05	0.00E+00
U-232	2.05E-02	2	2.34E-01	0.01	3.00E-05	2.88E-09
U-233	4.07E-05	2	2.34E-01	0.01	3.00E-05	5.72E-12
U-234	6.77E-01	2	2.34E-01	0.01	3.00E-05	9.51E-08
U-235	7.36E-03	2	2.34E-01	0.01	3.00E-05	1.03E-09
U-236	1.72E-01	2	2.34E-01	0.01	3.00E-05	2.42E-08
U-238	1.48E-01	2	2.34E-01	0.01	3.00E-05	2.08E-08
Zr-93	8.94E-01	2	2.34E-01	0.01	3.00E-05	1.26E-07

Event #:	Annualized Releases for All Category 1 Events (Ci/yr) - Input to GENII-S Code														Total Release per Nuclide (Ci/yr)
	1-01	1-02	1-03	1-04	1-05	1-06	1-07	1-08	1-09	1-10	1-11	1-12	1-13	1-14	
Co-60*	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.93E-03	3.85E-03	5.50E-03	5.50E-03	5.50E-03	2.23E-02
Fe-55*	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.61E-03	1.52E-02	2.17E-02	1.09E-02	2.17E-02	7.72E-02
Ac-227	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.92E-13	1.58E-12	2.26E-12	1.13E-12	2.26E-12	8.03E-12
Am-241	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.74E-05	1.95E-04	2.78E-04	1.39E-04	2.78E-04	9.88E-04
Am-242m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.14E-07	6.29E-07	8.98E-07	4.49E-07	8.98E-07	3.19E-06
Am-243	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.08E-06	2.17E-06	3.09E-06	1.55E-06	3.09E-06	1.10E-05
C-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.63E-08	3.27E-08	4.67E-08	2.33E-08	4.67E-08	1.66E-07
Cd-113m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.77E-07	7.54E-07	1.08E-06	5.38E-07	1.08E-06	3.82E-06
Cl-36	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.35E-10	6.69E-10	9.56E-10	4.78E-10	9.56E-10	3.39E-09
Cm-242	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.59E-07	5.19E-07	7.41E-07	3.70E-07	7.41E-07	2.63E-06
Cm-243	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.07E-07	1.01E-06	1.45E-06	7.24E-07	1.45E-06	5.14E-06
Cm-244	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.69E-05	1.34E-04	1.91E-04	9.56E-05	1.91E-04	6.79E-04
Cm-245	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.51E-08	3.02E-08	4.31E-08	2.16E-08	4.31E-08	1.53E-07
Cm-246	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.12E-09	1.02E-08	1.46E-08	7.31E-09	1.46E-08	5.19E-08
Co-60**	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.54E-05	3.08E-05	4.40E-05	2.20E-05	4.40E-05	1.56E-04
Cs-134	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.27E-06	1.65E-05	2.36E-05	1.18E-05	2.36E-05	8.38E-05
Cs-135	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.15E-07	2.30E-07	3.28E-07	1.64E-07	3.28E-07	1.16E-06
Cs-137	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.35E-02	2.70E-02	3.85E-02	1.93E-02	3.85E-02	1.37E-01
Eu-154	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.30E-05	6.60E-05	9.43E-05	4.72E-05	9.43E-05	3.35E-04
Eu-155	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.54E-06	5.08E-06	7.25E-06	3.63E-06	7.25E-06	2.57E-05
Fe-55**	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.71E-07	3.42E-07	4.88E-07	2.44E-07	4.88E-07	1.73E-06
H-3	1.60E+01	1.34E+00	1.44E+00	1.31E+01	1.12E+01	1.12E+01	1.12E+01	5.61E+00	5.61E+00	5.61E+00	1.12E+01	1.60E+01	8.01E+00	1.60E+01	1.34E+02
I-129	3.09E-03	2.58E-04	2.78E-04	2.54E-03	2.17E-03	2.17E-03	2.17E-03	1.08E-03	1.08E-03	1.08E-03	2.17E-03	3.09E-03	1.55E-03	3.09E-03	2.58E-02
Kr-85	1.59E+02	1.32E+01	1.43E+01	1.30E+02	1.11E+02	1.11E+02	1.11E+02	5.56E+01	5.56E+01	5.56E+01	1.11E+02	1.59E+02	7.94E+01	1.59E+02	1.33E+03
Nb-93m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.40E-07	1.28E-06	1.83E-06	9.14E-07	1.83E-06	6.49E-06
Nb-94	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.13E-08	8.26E-08	1.18E-07	5.90E-08	1.18E-07	4.19E-07
Ni-59	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.03E-07	2.06E-07	2.94E-07	1.47E-07	2.94E-07	1.04E-06
Ni-63	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.24E-05	2.48E-05	3.54E-05	1.77E-05	3.54E-05	1.26E-04
Np-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.22E-08	2.43E-08	3.47E-08	1.74E-08	3.47E-08	1.23E-07
Pa-231	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.46E-12	2.92E-12	4.17E-12	2.09E-12	4.17E-12	1.48E-11
Pb-210	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pd-107	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.14E-09	8.28E-09	1.18E-08	5.91E-09	1.18E-08	4.20E-08
Pm-147	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.86E-06	1.17E-05	1.67E-05	8.36E-06	1.67E-05	5.94E-05
Pu-238	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.13E-04	2.25E-04	3.22E-04	1.61E-04	3.22E-04	1.14E-03
Pu-239	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.71E-06	1.74E-05	2.49E-05	1.24E-05	2.49E-05	8.83E-05
Pu-240	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.56E-05	3.13E-05	4.47E-05	2.23E-05	4.47E-05	1.59E-04
Pu-241	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.22E-03	2.43E-03	3.47E-03	1.74E-03	3.47E-03	1.23E-02
Pu-242	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.07E-08	1.61E-07	2.30E-07	1.15E-07	2.30E-07	8.18E-07
Ra-226	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ra-228	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-106	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.05E-10	1.21E-09	1.73E-09	8.64E-10	1.73E-09	6.14E-09
Sb-125	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.78E-07	9.56E-07	1.36E-06	6.82E-07	1.36E-06	4.85E-06
Se-79	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.25E-09	4.50E-09	6.42E-09	3.21E-09	6.42E-09	2.28E-08

Event #:	Annualized Releases for All Category 1 Events (Ci/yr) - Input to GENII-S Code														Total Release per Nuclide (Ci/yr)
	1-01	1-02	1-03	1-04	1-05	1-06	1-07	1-08	1-09	1-10	1-11	1-12	1-13	1-14	
Sm-147	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sm-151	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.04E-05	2.08E-05	2.97E-05	1.48E-05	2.97E-05	1.05E-04
Sn-126	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.89E-08	3.79E-08	5.41E-08	2.71E-08	5.41E-08	1.92E-07
Sr-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.34E-03	2.68E-03	3.82E-03	1.91E-03	3.82E-03	1.36E-02
Tc-99	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.42E-07	8.85E-07	1.26E-06	6.32E-07	1.26E-06	4.49E-06
Th-229	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Th-230	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.28E-12	1.46E-11	2.08E-11	1.04E-11	2.08E-11	7.39E-11
Th-232	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-232	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.01E-09	2.02E-09	2.88E-09	1.44E-09	2.88E-09	1.02E-08
U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E-12	4.01E-12	5.72E-12	2.86E-12	5.72E-12	2.03E-11
U-234	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.33E-08	6.66E-08	9.51E-08	4.76E-08	9.51E-08	3.38E-07
U-235	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.62E-10	7.24E-10	1.03E-09	5.17E-10	1.03E-09	3.67E-09
U-236	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.46E-09	1.69E-08	2.42E-08	1.21E-08	2.42E-08	8.58E-08
U-238	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.28E-09	1.46E-08	2.08E-08	1.04E-08	2.08E-08	7.39E-08
Zr-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.40E-08	8.80E-08	1.26E-07	6.28E-08	1.26E-07	4.46E-07
Totals:	1.75E+02	1.46E+01	1.57E+01	1.43E+02	1.22E+02	1.22E+02	1.22E+02	6.12E+01	6.12E+01	6.12E+01	1.22E+02	1.75E+02	8.75E+01	1.75E+02	1.46E+03

* C0-60 and Fe-55 CRUD releases

** C0-60 and Fe-55 fuel gap releases

Validation Test Cases for Formulas Contained in this Workbook

Worksheet	Cell Range	Test Cell	Formula	Input	Output	Hand-Calculated Results*
Crud Source	D7	D7	=IF(D3="y",5902*EXP(-LN(2)*D5/2.73),0)	D3=y, D5=25	D7=10.3	D7=10.34
Crud Source	D8	D8	=IF(D3="y",7415*EXP(-LN(2)*D5/2.73),0)	D3=y, D5=25	D8=13.0	D8=12.99
Crud Source	D9	D9	=140*EXP(-LN(2)*D5/5.271)*IF(Input!E17=1,1,0.5)	D5=25, Input!E17=2	D9=2.6	D9=2.61
Crud Source	D10	D10	=1254*EXP(-LN(2)*D5/5.271)*IF(Input!E17=1,1,0.5)	D5=25, Input!E17=2	D10=23.4	D10=23.42
Crud Source	B20	B20	=(D7*D12)/1000000	D7=10.3, D12=449,003	B20=4.6	B20=4.62
Crud Source	B21	B21	=(D8*D13)/1000000	D8=13.0, D13=168,148	B21=2.2	B21=2.19
Crud Source	B22	B22	=(D9*D12)/1000000	D9=2.6, D12=449,003	B22=1.2	B22=1.17
Crud Source	B23	B23	=(D10*D13)/1000000	D10=23.4, D13=168,148	B23=3.9	B23=3.93
Cat. 1 X-Q Values	C8, C14	C8	=C6-((B8-B6)/(B7-B6))*(C6-C7)	C6=2.12E-7, B8=11000, B6=10000, B7=20000, C7=8.12E-8	C8=1.99E-7	C8=1.989E-7
RFs	H5:H12, H19:26	H5	=C5*D5*E5*F5*G5	C5=1, D5=0.3, E5=1, F5=1, G5=1	H5=0.30	H5=0.300
Cat.1 DBE Release	G5:G62	G5	=B5*C5*D5*E5*F5	B5=1.17, C5=2, D5=0.234, E5=0.01, F5=1.0	G5=5.5E-3	G5=5.476E-3

* Output values may differ slightly from hand calculations due to rounding errors. These differences are acceptable for the range of input values used in this calculation.

Attachment X

Category 2 DBE Dose Calculations

The following data contained in this attachment are from file **SR Cat. 2 TEDE Dose_Rev01.xls** (Attachment I):

Worksheet	Description	Page
Events-Frequencies	List of Category 2 Events and Frequencies	X-2
Avg Dose	Inhalation Dose (rem/FA) for Average Fuels (PWR & BWR)	X-3 to X-4
Max Dose	Inhalation Dose (rem/FA) for Maximum Fuels (PWR & BWR)	X-5 to X-6
Crud	Crud Source Term Calculations	X-7
The following worksheets are shown for Event 2-09, with Maximum BWR fuel, for illustration purposes only - the fuel type and number of SFAs involved are based upon user input:		
Groupings	Nuclides and Inhalation Dose Sorted by Group	X-8
Grouped Sources	Total Inhalation Dose for Each Group (sum of nuclides in each group)	X-9
RFs	Release Fractions for CSNF	X-10
χ-Q Values	Maximum Sector Acute χ/Q Values at 5-km, 8-km and 11-km	X-11
Submersion	Submersion Dose Due to H-3 and Kr-85	X-12
Gonad	Inhalation Dose to the Gonad	X-13
Breast	Inhalation Dose to the Breast	X-14
Lung	Inhalation Dose to the Lung	X-15
Marrow	Inhalation Dose to the Red Marrow	X-16
Bone Surface	Inhalation Dose to the Bone Surface	X-17
Thyroid	Inhalation Dose to the Thyroid	X-18
Remainder	Inhalation Dose to the Remainder of Organs	X-19
Whole Body	Effective Inhalation Dose to the Whole Body	X-20
Inputs	Input Parameters for each Category 2 event*	X-21 to X-34
Summary	Output Summary for each Category 2 event*	X-35 to X-48
Test Cases	Validation Test Cases for Formulas contained in this workbook	X-49

* Including non-mechanistic events NM-01 and NM-02

Category 2 Event Frequencies

Event #	Category 2 Events	Location	Occurs in Pool?	Material at Risk (# SFAs)		Sequence Frequency (per year)
				PWR	BWR	
2-01	Basket Collision During Transfer to Pool Storage	ATS Pool	Y	4	8	6.83E-03
2-02	Basket Collision During Transfer to Incline Transfer Canal	ATS Pool	Y	4	8	6.83E-03
2-03	Uncontrolled Descent of Incline Transfer Cart	ATS Pool	Y	4	8	6.83E-03
2-04	Handling Equipment Drop Onto SFA in Pool	ATS Pool	Y	1	1	2.38E-03
2-05	Handling Equipment Drop Onto SFA in Hot Cell	ATS Hot Cell	N	1	1	2.38E-03
2-06	Handling Equipment Drop Onto SFA Basket in Pool	ATS Pool	Y	4	8	1.74E-03
2-07	Handling Equipment Drop Onto SFA Basket in Hot Cell	ATS Hot Cell	N	4	8	6.95E-05
2-08	Unsealed DC Collision	DC Handling Cell	N	21	44	1.80E-03
2-09	Unsealed DC Drop and Slapdown	DC Handling Cell	N	21	44	8.40E-03
2-10	Handling Equipment Drop Onto Unsealed DC	DC Handling Cell	N	21	44	1.10E-04
2-11	Shipping Cask Drop Into Cask Preparation Pit	ATS Cask Preparation Pit	N	24	68	8.68E-03
2-12	Shipping Cask Drop Into Cask Unloading Pool	ATS Pool	Y	24	68	8.68E-03
NM-01	Non-Mechanistic Shipping Cask Leak	Carrier Bay	N	24	68	NM
NM-02	Non-Mechanistic Preclosure Early Failure of a WP	Subsurface	N	21	44	NM

* A non-mechanistic release was assumed without a frequency analysis. Sealed cask and WP breaches are expected to be beyond design basis events.

Inhalation Dose for Average PWR Fuel

Nuclide	AVERAGE PWR INHALATION DOSE (REM/FA)*								MAR (Curies/FA)
	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Whole Body	
Ac-227	2.12E+03	6.31E-01	9.17E+04	1.39E+04	1.73E+05	3.85E-01	7.98E+03	2.08E+04	1.61E-05
Am-241	2.38E+11	1.96E+07	1.35E+11	1.27E+12	1.59E+13	1.17E+07	5.73E+11	8.77E+11	1.98E+03
Am-242m	7.59E+08	3.26E+04	9.93E+07	4.00E+09	5.01E+10	1.33E+04	1.77E+09	2.72E+09	6.39E+00
Am-243	2.65E+09	1.24E+06	1.45E+09	1.41E+10	1.77E+11	6.75E+05	6.30E+09	9.72E+09	2.20E+01
C-14	7.81E+00	7.81E+00	7.81E+00	7.81E+00	7.81E+00	7.81E+00	7.81E+00	7.81E+00	3.32E-01
Cd-113m	1.34E+05	1.34E+05	1.16E+07	1.34E+05	1.34E+05	1.34E+05	5.27E+06	3.05E+06	7.66E+00
Cl-36	1.27E+01	1.27E+01	1.15E+03	1.27E+01	1.27E+01	1.27E+01	1.35E+01	1.49E+02	6.80E-03
Cm-242	1.11E+07	1.84E+04	3.02E+08	7.60E+07	9.50E+08	1.83E+04	4.78E+07	9.10E+07	5.27E+00
Cm-243	7.89E+08	2.40E+05	7.39E+08	4.50E+09	5.60E+10	1.46E+05	2.20E+09	3.16E+09	1.03E+01
Cm-244	8.00E+10	5.23E+06	9.71E+10	4.72E+11	5.89E+12	5.08E+06	2.41E+11	3.37E+11	1.36E+03
Cm-245	3.83E+07	7.60E+03	2.04E+07	2.03E+08	2.54E+09	4.18E+03	9.04E+07	1.40E+08	3.07E-01
Cm-246	1.29E+07	1.54E+03	7.00E+06	6.85E+07	8.54E+08	8.70E+02	3.06E+07	4.71E+07	1.04E-01
Co-60	5.51E+06	2.13E+07	4.00E+08	1.99E+07	1.56E+07	1.88E+07	4.17E+07	6.84E+07	3.13E+02
Cs-134	1.21E+06	1.01E+06	1.10E+06	1.10E+06	1.03E+06	1.03E+06	1.30E+06	1.17E+06	2.52E+01
Cs-135	1.55E+03	1.55E+03	1.83E+03	1.55E+03	1.55E+03	1.55E+03	1.55E+03	1.59E+03	3.50E-01
Cs-137	1.33E+09	1.19E+09	1.34E+09	1.26E+09	1.21E+09	1.21E+09	1.39E+09	1.31E+09	4.11E+04
Eu-154	2.90E+07	3.85E+07	1.97E+08	2.63E+08	1.30E+09	1.77E+07	2.81E+08	1.92E+08	6.71E+02
Eu-155	6.80E+04	1.17E+05	2.27E+06	2.73E+06	2.90E+07	4.58E+04	2.12E+06	2.14E+06	5.16E+01
Fe-55	2.30E+03	2.23E+03	1.36E+04	2.26E+03	2.25E+03	2.38E+03	5.61E+03	4.64E+03	3.47E+00
H-3	7.30E+03	7.30E+03	7.30E+03	7.30E+03	7.30E+03	7.30E+03	7.30E+03	7.30E+03	1.14E+02
I-129	7.07E+00	1.70E+01	Yearly Class I	1.14E+01	1.12E+01	1.27E+05	9.61E+00	3.82E+03	2.20E-02
Kr-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.13E+03
Nb-93m	7.46E+03	2.10E+03	3.10E+06	5.48E+03	1.37E+04	5.48E+02	1.46E+04	3.80E+05	1.30E+01
Nb-94	1.37E+04	6.95E+04	2.32E+06	7.02E+04	6.12E+04	6.89E+04	1.38E+05	3.46E+05	8.39E-01
Ni-59	8.43E+02	8.12E+02	9.28E+03	8.20E+02	8.12E+02	8.82E+02	1.08E+03	1.92E+03	2.09E+00
Ni-63	2.30E+05	2.30E+05	2.86E+06	2.30E+05	2.30E+05	2.30E+05	3.42E+05	5.80E+05	2.52E+02
Np-237	2.71E+07	1.54E+04	1.47E+07	2.39E+08	2.99E+09	1.22E+04	2.14E+07	1.33E+08	2.47E-01
Pa-231	3.36E-01	6.21E-01	8.21E+04	3.16E+04	3.96E+05	4.89E-01	2.33E+01	2.55E+04	2.97E-05
Pb-210	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pd-107	3.27E-02	3.27E-02	8.87E+03	1.77E-01	4.70E-01	3.27E-02	3.02E+01	1.07E+03	8.41E-02
Pm-147	3.63E+00	1.59E+01	3.41E+07	7.09E+05	8.85E+06	8.72E+00	6.87E+05	4.65E+06	1.19E+02
Pu-238	8.81E+10	3.73E+06	2.71E+12	4.91E+11	6.14E+12	3.27E+06	2.32E+11	6.60E+11	2.29E+03
Pu-239	7.86E+09	2.61E+05	2.12E+11	4.30E+10	5.38E+11	2.46E+05	1.98E+10	5.46E+10	1.77E+02
Pu-240	1.41E+10	5.09E+05	3.80E+11	7.73E+10	9.66E+11	4.42E+05	3.55E+10	9.81E+10	3.18E+02
Pu-241	2.52E+10	1.96E+06	2.91E+11	1.31E+11	1.63E+12	8.36E+05	5.50E+10	1.22E+11	2.47E+04
Pu-242	6.92E+07	2.64E+03	1.86E+09	3.79E+08	4.74E+09	2.25E+03	1.74E+08	4.81E+08	1.64E+00
Ra-226	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ra-228	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-106	5.92E+01	8.10E+01	4.73E+04	8.01E+01	7.33E+01	7.83E+01	5.46E+02	5.88E+03	1.23E-02
Sb-125	1.29E+04	1.49E+04	7.80E+05	1.92E+04	3.51E+04	1.16E+04	5.21E+04	1.19E+05	9.71E+00
Se-79	1.01E+02	1.01E+02	1.66E+03	1.01E+02	1.01E+02	1.01E+02	6.37E+02	4.49E+02	4.57E-02
Sm-147	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sm-151	3.15E+01	1.16E+02	2.55E+06	8.59E+06	1.08E+08	1.03E+01	5.86E+06	6.33E+06	2.11E+02
Sn-126	7.05E+03	7.68E+03	2.15E+05	2.41E+04	4.74E+04	6.98E+03	1.71E+04	3.84E+04	3.85E-01
Sr-90	2.66E+08	2.66E+08	3.75E+08	3.38E+10	7.32E+10	2.66E+08	3.38E+08	6.51E+09	2.72E+04
Tc-99	1.33E+03	1.33E+03	5.55E+05	1.33E+03	1.33E+03	3.56E+04	2.08E+04	7.47E+04	8.99E+00
Th-229	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Th-230	9.42E+01	9.42E+01	1.64E+05	3.83E+04	4.77E+05	9.42E+01	2.45E+02	3.87E+04	1.48E-04
Th-232	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-232	1.28E+03	2.02E+03	1.12E+08	3.55E+04	5.42E+05	1.84E+03	4.44E+04	1.35E+07	2.05E-02
U-233	4.05E-01	4.11E-01	4.58E+04	1.11E+01	1.75E+02	4.07E-01	1.63E+01	5.51E+03	4.07E-05
U-234	6.64E+03	6.71E+03	7.46E+08	1.81E+05	2.83E+06	6.64E+03	2.66E+05	8.98E+07	6.77E-01
U-235	7.73E+01	1.46E+02	7.52E+06	1.95E+03	2.86E+04	1.12E+02	2.78E+03	9.04E+05	7.36E-03
U-236	1.60E+03	1.62E+03	1.79E+08	4.35E+04	6.81E+05	1.60E+03	7.57E+02	2.16E+07	1.72E-01
U-238	1.33E+03	1.59E+03	1.46E+08	3.77E+04	5.53E+05	1.49E+03	5.26E+04	1.75E+07	1.48E-01
Zr-93	1.85E+01	3.97E+01	1.09E+04	1.49E+05	1.83E+06	1.47E+01	5.09E+02	7.43E+04	8.94E-01

Nuclide	AVERAGE PWR SUBMERSION DOSE RATE (rem-m^3/FA-s)**										MAR (Curies/FA)
	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Whole Body	Skin	Eye Lens	
H-3	0.00E+00	0.00E+00	1.16E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.40E-04	0.00E+00	0	1.14E+02
Kr-85	4.89E-01	5.60E-01	4.77E-01	4.56E-01	9.20E-01	4.93E-01	4.56E-01	4.98E-01	5.52E+01	0	1.13E+03
Totals:	4.89E-01	5.60E-01	4.78E-01	4.56E-01	9.20E-01	4.93E-01	4.56E-01	4.98E-01	5.52E+01	0.00E+00	

* Inhalation organ doses are cut/pasted from SR Source Terms.xls/Avg PWR/BWR Dose

** Submersion organ doses are cut/pasted from SR Source Terms.xls/Submersion Dose

Inhalation Dose for Average BWR Fuel

Nuclide	AVERAGE BWR INHALATION DOSE (REM/FA)*								MAR
	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Whole Body	(Curies/FA)
Ac-227	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Am-241	6.71E+10	5.51E+06	3.80E+10	3.59E+11	4.48E+12	3.30E+06	1.61E+11	2.47E+11	5.58E+02
Am-242m	2.58E+08	1.11E+04	3.37E+07	1.36E+09	1.70E+10	4.53E+03	6.01E+08	9.22E+08	2.17E+00
Am-243	6.45E+08	3.01E+05	3.52E+08	3.42E+09	4.30E+10	1.64E+05	1.53E+09	2.36E+09	5.35E+00
C-14	4.12E+00	4.12E+00	4.12E+00	4.12E+00	4.12E+00	4.12E+00	4.12E+00	4.12E+00	1.75E-01
Cd-113m	3.95E+04	3.95E+04	3.42E+06	3.95E+04	3.95E+04	3.95E+04	1.56E+06	9.00E+05	2.26E+00
Cl-36	5.46E+00	5.46E+00	4.94E+02	5.46E+00	5.46E+00	5.46E+00	5.81E+00	6.42E+01	2.93E-03
Cm-242	3.78E+06	6.25E+03	1.03E+08	2.58E+07	3.23E+08	6.23E+03	1.62E+07	3.09E+07	1.79E+00
Cm-243	1.90E+08	5.77E+04	1.78E+08	1.08E+09	1.35E+10	3.51E+04	5.29E+08	7.62E+08	2.48E+00
Cm-244	1.51E+10	9.85E+05	1.83E+10	8.88E+10	1.11E+12	9.57E+05	4.53E+10	6.35E+10	2.56E+02
Cm-245	5.04E+06	1.00E+03	2.69E+06	2.68E+07	3.35E+08	5.50E+02	1.19E+07	1.84E+07	4.04E-02
Cm-246	1.79E+06	2.15E+02	9.76E+05	9.55E+06	1.19E+08	1.21E+02	4.26E+06	6.56E+06	1.45E-02
Co-60	7.75E+05	3.00E+06	5.62E+07	2.80E+06	2.20E+06	2.64E+06	5.86E+06	9.62E+06	4.40E+01
Cs-134	3.04E+05	2.53E+05	2.76E+05	2.76E+05	2.57E+05	2.60E+05	3.25E+05	2.93E+05	6.32E+00
Cs-135	6.17E+02	6.17E+02	7.25E+02	6.17E+02	6.17E+02	6.17E+02	6.17E+02	6.30E+02	1.39E-01
Cs-137	4.51E+08	4.03E+08	4.54E+08	4.27E+08	4.08E+08	4.08E+08	4.69E+08	4.44E+08	1.39E+04
Eu-154	7.79E+06	1.03E+07	5.27E+07	7.06E+07	3.48E+08	4.76E+06	7.53E+07	5.15E+07	1.80E+02
Eu-155	2.16E+04	3.73E+04	7.22E+05	8.68E+05	9.22E+06	1.46E+04	6.74E+05	6.81E+05	1.64E+01
Fe-55	7.22E+02	7.02E+02	4.27E+03	7.10E+02	7.06E+02	7.46E+02	1.76E+03	1.46E+03	1.09E+00
H-3	2.53E+03	2.53E+03	2.53E+03	2.53E+03	2.53E+03	2.53E+03	2.53E+03	2.53E+03	3.95E+01
I-129	2.39E+00	5.75E+00	8.63E+00	3.85E+00	3.79E+00	4.29E+04	3.24E+00	1.29E+03	7.43E-03
Kr-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.81E+02
Nb-93m	2.72E+02	7.65E+01	1.13E+05	2.00E+02	4.98E+02	2.00E+01	5.33E+02	1.39E+04	4.74E-01
Nb-94	3.06E+02	1.55E+03	5.18E+04	1.56E+03	1.36E+03	1.54E+03	3.08E+03	7.72E+03	1.87E-02
Ni-59	2.03E+02	1.95E+02	2.23E+03	1.97E+02	1.95E+02	2.12E+02	2.61E+02	4.62E+02	5.03E-01
Ni-63	5.36E+04	5.36E+04	6.67E+05	5.36E+04	5.36E+04	5.36E+04	7.97E+04	1.35E+05	5.87E+01
Np-237	7.55E+06	4.31E+03	4.10E+06	6.68E+07	8.34E+08	3.42E+03	5.97E+06	3.72E+07	6.89E-02
Pa-231	1.57E-01	2.91E-01	3.84E+04	1.48E+04	1.85E+05	2.29E-01	1.09E+01	1.19E+04	1.39E-05
Pb-210	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pd-107	1.03E-02	1.03E-02	2.79E+03	5.57E-02	1.48E-01	1.03E-02	9.52E+00	3.38E+02	2.65E-02
Pm-147	1.21E+00	5.30E+00	1.14E+07	2.37E+05	2.96E+06	2.92E+00	2.30E+05	1.55E+06	3.98E+01
Pu-238	2.25E+10	9.52E+05	6.93E+11	1.26E+11	1.57E+12	8.35E+05	5.93E+10	1.69E+11	5.85E+02
Pu-239	2.38E+09	7.90E+04	6.39E+10	1.30E+10	1.63E+11	7.42E+04	5.98E+09	1.65E+10	5.35E+01
Pu-240	5.06E+09	1.83E+05	1.36E+11	2.77E+10	3.46E+11	1.59E+05	1.27E+10	3.52E+10	1.14E+02
Pu-241	6.92E+09	5.37E+05	7.98E+10	3.59E+10	4.47E+11	2.30E+05	1.51E+10	3.35E+10	6.78E+03
Pu-242	2.15E+07	8.19E+02	5.78E+08	1.18E+08	1.47E+09	6.99E+02	5.39E+07	1.49E+08	5.09E-01
Ra-226	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ra-228	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-106	1.44E+01	1.98E+01	1.15E+04	1.95E+01	1.79E+01	1.91E+01	1.33E+02	1.44E+03	3.00E-03
Sb-125	3.85E+03	4.45E+03	2.32E+05	5.72E+03	1.05E+04	3.46E+03	1.55E+04	3.53E+04	2.89E+00
Se-79	3.52E+01	3.52E+01	5.77E+02	3.52E+01	3.52E+01	3.52E+01	2.22E+02	1.56E+02	1.59E-02
Sm-147	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sm-151	8.04E+00	2.97E+01	6.50E+05	2.19E+06	2.75E+07	2.63E+00	1.50E+06	1.62E+06	5.39E+01
Sn-126	2.33E+03	2.53E+03	7.10E+04	7.94E+03	1.56E+04	2.30E+03	5.64E+03	1.27E+04	1.27E-01
Sr-90	9.32E+07	9.32E+07	1.32E+08	1.19E+10	2.57E+10	9.32E+07	1.19E+08	2.28E+09	9.54E+03
Tc-99	4.72E+02	4.72E+02	1.98E+05	4.72E+02	4.72E+02	1.27E+04	7.41E+03	2.66E+04	3.20E+00
Th-229	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Th-230	3.88E+01	3.88E+01	6.76E+04	1.58E+04	1.96E+05	3.88E+01	1.01E+02	1.59E+04	6.09E-05
Th-232	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-232	2.90E+02	4.57E+02	2.54E+07	8.03E+03	1.23E+05	4.17E+02	1.01E+04	3.06E+06	4.64E-03
U-233	1.13E-01	1.15E-01	1.28E+04	3.12E+00	4.89E+01	1.14E-01	4.56E+00	1.54E+03	1.14E-05
U-234	2.44E+03	2.47E+03	2.75E+08	6.65E+04	1.04E+06	2.44E+03	9.77E+04	3.30E+07	2.49E-01
U-235	2.75E+01	5.21E+01	2.68E+06	6.93E+02	1.02E+04	3.98E+01	9.89E+02	3.22E+05	2.62E-03
U-236	5.81E+02	5.88E+02	6.53E+07	1.58E+04	2.48E+05	5.81E+02	2.76E+02	7.85E+06	6.26E-02
U-238	5.66E+02	6.80E+02	6.22E+07	1.61E+04	2.36E+05	6.38E+02	2.25E+04	7.48E+06	6.32E-02
Zr-93	6.98E+00	1.50E+01	4.13E+03	5.62E+04	6.93E+05	5.57E+00	1.93E+02	2.81E+04	3.38E-01

Nuclide	AVERAGE BWR SUBMERSION DOSE RATE (rem-m^3/FA-s)**										MAR
	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Whole Body	Skin	Eye Lens	(Curies/FA)
H-3	0.00E+00	0.00E+00	4.02E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.84E-05	0.00E+00	0	3.95E+01
Kr-85	1.65E-01	1.89E-01	1.61E-01	1.54E-01	3.10E-01	1.66E-01	1.54E-01	1.68E-01	1.86E+01	0	3.81E+02
Totals:	1.65E-01	1.89E-01	1.61E-01	1.54E-01	3.10E-01	1.66E-01	1.54E-01	1.68E-01	1.86E+01	0.00E+00	

* Inhalation organ doses are cut/pasted from SR Source Terms.xls/Avg PWR/BWR Dose

** Submersion organ doses are cut/pasted from SR Source Terms.xls/Submersion Dose

Inhalation Dose for Maximum PWR Fuel

Nuclide	MAXIMUM PWR INHALATION DOSE (REM/FA)*								MAR (Curies/FA)
	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Whole Body	
Ac-227	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Am-241	1.05E+11	8.60E+06	5.93E+10	5.61E+11	6.99E+12	5.16E+06	2.52E+11	3.86E+11	8.71E+02
Am-242m	1.21E+09	5.21E+04	1.59E+08	6.38E+09	8.00E+10	2.13E+04	2.82E+09	4.33E+09	1.02E+01
Am-243	6.30E+09	2.94E+06	3.44E+09	3.34E+10	4.19E+11	1.60E+06	1.49E+10	2.31E+10	5.22E+01
C-14	1.15E+01	1.15E+01	1.15E+01	1.15E+01	1.15E+01	1.15E+01	1.15E+01	1.15E+01	4.89E-01
Cd-113m	6.67E+05	6.67E+05	5.78E+07	6.67E+05	6.67E+05	6.67E+05	2.63E+07	1.52E+07	3.82E+01
Cl-36	1.81E+01	1.81E+01	1.63E+03	1.81E+01	1.81E+01	1.81E+01	1.92E+01	2.12E+02	9.69E-03
Cm-242	7.23E+07	1.20E+05	1.97E+09	4.95E+08	6.18E+09	1.19E+05	3.11E+08	5.92E+08	3.43E+01
Cm-243	2.93E+09	8.91E+05	2.75E+09	1.67E+10	2.08E+11	5.43E+05	8.16E+09	1.18E+10	3.83E+01
Cm-244	6.59E+11	4.31E+07	8.00E+11	3.89E+12	4.85E+13	4.19E+07	1.98E+12	2.78E+12	1.12E+04
Cm-245	1.76E+08	3.49E+04	9.39E+07	9.34E+08	1.17E+10	1.92E+04	4.15E+08	6.42E+08	1.41E+00
Cm-246	1.04E+08	1.24E+04	5.64E+07	5.52E+08	6.88E+09	7.01E+03	2.46E+08	3.79E+08	8.38E-01
Co-60	9.97E+07	3.85E+08	7.22E+09	3.60E+08	2.83E+08	3.39E+08	7.54E+08	1.24E+09	5.66E+03
Cs-134	1.79E+09	1.49E+09	1.62E+09	1.62E+09	1.51E+09	1.53E+09	1.91E+09	1.73E+09	3.72E+04
Cs-135	2.66E+03	2.66E+03	3.12E+03	2.66E+03	2.66E+03	2.66E+03	2.66E+03	2.72E+03	5.99E-01
Cs-137	3.20E+09	2.86E+09	3.22E+09	3.03E+09	2.90E+09	2.90E+09	3.33E+09	3.15E+09	9.87E+04
Eu-154	2.50E+08	3.31E+08	1.69E+09	2.26E+09	1.12E+10	1.52E+08	2.41E+09	1.65E+09	5.77E+03
Eu-155	2.21E+06	3.82E+06	7.40E+07	8.89E+07	9.45E+08	1.49E+06	6.90E+07	6.98E+07	1.68E+03
Fe-55	4.53E+05	4.40E+05	2.68E+06	4.45E+05	4.43E+05	4.68E+05	1.11E+06	9.14E+05	6.84E+02
H-3	3.02E+04	3.02E+04	3.02E+04	3.02E+04	3.02E+04	3.02E+04	3.02E+04	3.02E+04	4.72E+02
I-129	1.09E+01	2.61E+01	Yearly Clas	1.75E+01	1.73E+01	1.95E+05	1.48E+01	5.87E+03	3.38E-02
Kr-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.63E+03
Nb-93m	2.60E+04	7.32E+03	1.08E+07	1.91E+04	4.77E+04	1.91E+03	5.11E+04	1.33E+06	4.54E+01
Nb-94	2.08E+04	1.05E+05	3.51E+06	1.06E+05	9.26E+04	1.04E+05	2.09E+05	5.24E+05	1.27E+00
Ni-59	1.12E+03	1.08E+03	1.23E+04	1.09E+03	1.08E+03	1.17E+03	1.44E+03	2.55E+03	2.78E+00
Ni-63	3.80E+05	3.80E+05	4.73E+06	3.80E+05	3.80E+05	3.80E+05	5.65E+05	9.57E+05	4.16E+02
Np-237	4.22E+07	2.41E+04	2.29E+07	3.73E+08	4.66E+09	1.91E+04	3.33E+07	2.08E+08	3.85E-01
Pa-231	4.81E-01	8.88E-01	1.17E+05	4.53E+04	5.66E+05	7.00E-01	3.33E+01	3.65E+04	4.25E-05
Pb-210	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pd-107	5.63E-02	5.63E-02	1.53E+04	3.05E-01	8.10E-01	5.63E-02	5.21E+01	1.85E+03	1.45E-01
Pm-147	7.14E+02	3.12E+03	6.70E+09	1.39E+08	1.74E+09	1.71E+03	1.35E+08	9.14E+08	2.34E+04
Pu-238	2.37E+11	1.00E+07	7.29E+12	1.32E+12	1.65E+13	8.80E+06	6.25E+11	1.78E+12	6.16E+03
Pu-239	8.21E+09	2.73E+05	2.21E+11	4.50E+10	5.62E+11	2.57E+05	2.07E+10	5.70E+10	1.85E+02
Pu-240	1.73E+10	6.25E+05	4.66E+11	9.48E+10	1.18E+12	5.43E+05	4.36E+10	1.20E+11	3.90E+02
Pu-241	8.08E+10	6.26E+06	9.31E+11	4.19E+11	5.21E+12	2.68E+06	1.76E+11	3.91E+11	7.91E+04
Pu-242	1.27E+08	4.84E+03	3.42E+09	6.96E+08	8.70E+09	4.13E+03	3.19E+08	8.82E+08	3.01E+00
Ra-226	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ra-228	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-106	6.11E+07	8.36E+07	4.89E+10	8.27E+07	7.57E+07	8.08E+07	5.64E+08	6.08E+09	1.27E+04
Sb-125	2.73E+06	3.16E+06	1.65E+08	4.06E+06	7.42E+06	2.46E+06	1.10E+07	2.50E+07	2.05E+03
Se-79	1.54E+02	1.54E+02	2.52E+03	1.54E+02	1.54E+02	1.54E+02	9.69E+02	6.83E+02	6.95E-02
Sm-147	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sm-151	4.67E+01	1.73E+02	3.78E+06	1.27E+07	1.60E+08	1.53E+01	8.70E+06	9.39E+06	3.13E+02
Sn-126	1.15E+04	1.25E+04	3.51E+05	3.93E+04	7.74E+04	1.14E+04	2.79E+04	6.26E+04	6.28E-01
Sr-90	6.15E+08	6.15E+08	8.69E+08	7.83E+10	1.69E+11	6.15E+08	7.83E+08	1.51E+10	6.30E+04
Tc-99	1.89E+03	1.89E+03	7.91E+05	1.89E+03	1.89E+03	5.07E+04	2.96E+04	1.06E+05	1.28E+01
Th-229	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Th-230	2.27E+01	2.27E+01	3.95E+04	9.21E+03	1.15E+05	2.27E+01	5.90E+01	9.32E+03	3.56E-05
Th-232	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-232	3.32E+03	5.23E+03	2.91E+08	9.19E+04	1.40E+06	4.77E+03	1.15E+05	3.50E+07	5.31E-02
U-233	2.41E-01	2.44E-01	2.72E+04	6.62E+00	1.04E+02	2.42E-01	9.67E+00	3.27E+03	2.42E-05
U-234	5.35E+03	5.41E+03	6.02E+08	1.46E+05	2.28E+06	5.35E+03	2.14E+05	7.24E+07	5.46E-01
U-235	4.36E+01	8.25E+01	4.24E+06	1.10E+03	1.61E+04	6.31E+01	1.57E+03	5.10E+05	4.15E-03
U-236	2.08E+03	2.11E+03	2.34E+08	5.66E+04	8.87E+05	2.08E+03	9.86E+02	2.81E+07	2.24E-01
U-238	1.28E+03	1.54E+03	1.41E+08	3.64E+04	5.34E+05	1.44E+03	5.08E+04	1.69E+07	1.43E-01
Zr-93	2.75E+01	5.91E+01	1.62E+04	2.21E+05	2.73E+06	2.19E+01	7.58E+02	1.10E+05	1.33E+00

Nuclide	MAXIMUM PWR SUBMERSION DOSE RATE (rem-m^3/FA-s)**										MAR (Curies/FA)
	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Whole Body	Skin	Eye Lens	
H-3	0.00E+00	0.00E+00	4.80E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.78E-04	0.00E+00	0	4.72E+02
Kr-85	2.44E+00	2.79E+00	2.37E+00	2.27E+00	4.58E+00	2.46E+00	2.27E+00	2.48E+00	2.75E+02	0	5.63E+03
Totals:	2.44E+00	2.79E+00	2.38E+00	2.27E+00	4.58E+00	2.46E+00	2.27E+00	2.48E+00	2.75E+02	0.00E+00	

* Inhalation organ doses are cut/pasted from SR Source Terms.xls/Max PWR/BWR Dose

** Submersion organ doses are cut/pasted from SR Source Terms.xls/Submersion Dose

Inhalation Dose for Maximum BWR Fuel

Nuclide	MAXIMUM BWR INHALATION DOSE (REM/FA)*								MAR (Curies/FA)
	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Whole Body	
Ac-227	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Am-241	3.20E+10	2.63E+06	1.81E+10	1.71E+11	2.14E+12	1.57E+06	7.70E+10	1.18E+11	2.66E+02
Am-242m	4.04E+08	1.74E+04	5.28E+07	2.13E+09	2.67E+10	7.10E+03	9.41E+08	1.44E+09	3.40E+00
Am-243	2.33E+09	1.09E+06	1.27E+09	1.24E+10	1.55E+11	5.92E+05	5.53E+09	8.52E+09	1.93E+01
C-14	7.44E+00	7.44E+00	7.44E+00	7.44E+00	7.44E+00	7.44E+00	7.44E+00	7.44E+00	3.16E-01
Cd-113m	2.43E+05	2.43E+05	2.10E+07	2.43E+05	2.43E+05	2.43E+05	9.57E+06	5.53E+06	1.39E+01
Cl-36	9.31E+00	9.31E+00	8.42E+02	9.31E+00	9.31E+00	9.31E+00	9.90E+00	1.09E+02	4.99E-03
Cm-242	2.38E+07	3.95E+04	6.48E+08	1.63E+08	2.04E+09	3.93E+04	1.02E+08	1.95E+08	1.13E+01
Cm-243	8.58E+08	2.61E+05	8.04E+08	4.89E+09	6.09E+10	1.59E+05	2.39E+09	3.44E+09	1.12E+01
Cm-244	2.32E+11	1.52E+07	2.82E+11	1.37E+12	1.71E+13	1.48E+07	6.99E+11	9.79E+11	3.95E+03
Cm-245	4.41E+07	8.76E+03	2.36E+07	2.34E+08	2.93E+09	4.82E+03	1.04E+08	1.61E+08	3.54E-01
Cm-246	3.67E+07	4.40E+03	2.00E+07	1.96E+08	2.44E+09	2.48E+03	8.73E+07	1.34E+08	2.97E-01
Co-60	1.51E+07	5.83E+07	1.09E+09	5.45E+07	4.28E+07	5.13E+07	1.14E+08	1.87E+08	8.56E+02
Cs-134	5.58E+08	4.64E+08	5.06E+08	5.06E+08	4.72E+08	4.76E+08	5.97E+08	5.38E+08	1.16E+04
Cs-135	1.25E+03	1.25E+03	1.47E+03	1.25E+03	1.25E+03	1.25E+03	1.25E+03	1.28E+03	2.82E-01
Cs-137	1.25E+09	1.12E+09	1.26E+09	1.19E+09	1.14E+09	1.14E+09	1.31E+09	1.24E+09	3.87E+04
Eu-154	7.92E+07	1.05E+08	5.36E+08	7.18E+08	3.54E+09	4.83E+07	7.65E+08	5.23E+08	1.83E+03
Eu-155	8.39E+05	1.45E+06	2.80E+07	3.37E+07	3.58E+08	5.66E+05	2.62E+07	2.64E+07	6.37E+02
Fe-55	1.56E+05	1.51E+05	9.22E+05	1.53E+05	1.52E+05	1.61E+05	3.80E+05	3.14E+05	2.35E+02
H-3	1.13E+04	1.13E+04	1.13E+04	1.13E+04	1.13E+04	1.13E+04	1.13E+04	1.13E+04	1.76E+02
I-129	4.37E+00	1.05E+01	1.58E+01	7.04E+00	6.94E+00	7.85E+04	5.94E+00	2.36E+03	1.36E-02
Kr-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.03E+03
Nb-93m	7.00E+02	1.97E+02	2.91E+05	5.15E+02	1.28E+03	5.15E+01	1.37E+03	3.57E+04	1.22E+00
Nb-94	5.54E+02	2.81E+03	9.38E+04	2.83E+03	2.47E+03	2.78E+03	5.58E+03	1.40E+04	3.39E-02
Ni-59	3.15E+02	3.03E+02	3.46E+03	3.06E+02	3.03E+02	3.29E+02	4.04E+02	7.17E+02	7.80E-01
Ni-63	1.06E+05	1.06E+05	1.32E+06	1.06E+05	1.06E+05	1.06E+05	1.58E+05	2.67E+05	1.16E+02
Np-237	1.46E+07	8.32E+03	7.92E+06	1.29E+08	1.61E+09	6.59E+03	1.15E+07	7.18E+07	1.33E-01
Pa-231	3.33E-01	6.15E-01	8.13E+04	3.13E+04	3.92E+05	4.84E-01	2.31E+01	2.53E+04	2.94E-05
Pb-210	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pd-107	2.21E-02	2.21E-02	6.01E+03	1.20E-01	3.18E-01	2.21E-02	2.05E+01	7.27E+02	5.70E-02
Pm-147	2.28E+02	9.94E+02	2.14E+09	4.44E+07	5.55E+08	5.47E+02	4.31E+07	2.91E+08	7.46E+03
Pu-238	8.12E+10	3.44E+06	2.50E+12	4.53E+11	5.66E+12	3.01E+06	2.14E+11	6.08E+11	2.11E+03
Pu-239	2.38E+09	7.91E+04	6.41E+10	1.30E+10	1.63E+11	7.44E+04	5.99E+09	1.65E+10	5.36E+01
Pu-240	6.57E+09	2.37E+05	1.77E+11	3.60E+10	4.50E+11	2.06E+05	1.65E+10	4.56E+10	1.48E+02
Pu-241	2.30E+10	1.78E+06	2.65E+11	1.19E+11	1.48E+12	7.62E+05	5.01E+10	1.11E+11	2.25E+04
Pu-242	5.31E+07	2.03E+03	1.43E+09	2.91E+08	3.64E+09	1.73E+03	1.33E+08	3.69E+08	1.26E+00
Ra-226	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ra-228	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-106	1.58E+07	2.17E+07	1.27E+10	2.14E+07	1.96E+07	2.09E+07	1.46E+08	1.57E+09	3.29E+03
Sb-125	8.27E+05	9.56E+05	4.99E+07	1.23E+06	2.25E+06	7.44E+05	3.33E+06	7.58E+06	6.21E+02
Se-79	6.39E+01	6.39E+01	1.05E+03	6.39E+01	6.39E+01	6.39E+01	4.03E+02	2.84E+02	2.89E-02
Sm-147	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sm-151	1.23E+01	4.53E+01	9.91E+05	3.35E+06	4.20E+07	4.01E+00	2.28E+06	2.46E+06	8.22E+01
Sn-126	4.62E+03	5.03E+03	1.41E+05	1.58E+04	3.10E+04	4.57E+03	1.12E+04	2.51E+04	2.52E-01
Sr-90	2.46E+08	2.46E+08	3.48E+08	3.13E+10	6.78E+10	2.46E+08	3.13E+08	6.03E+09	2.52E+04
Tc-99	7.90E+02	7.90E+02	3.31E+05	7.90E+02	7.90E+02	2.12E+04	1.24E+04	4.45E+04	5.35E+00
Th-229	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Th-230	1.30E+01	1.30E+01	2.28E+04	5.30E+03	6.61E+04	1.30E+01	3.40E+01	5.36E+03	2.05E-05
Th-232	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-232	1.25E+03	1.97E+03	1.10E+08	3.46E+04	5.28E+05	1.80E+03	4.34E+04	1.32E+07	2.00E-02
U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-234	2.22E+03	2.24E+03	2.49E+08	6.04E+04	9.45E+05	2.22E+03	8.86E+04	3.00E+07	2.26E-01
U-235	9.88E+00	1.87E+01	9.60E+05	2.49E+02	3.65E+03	1.43E+01	3.55E+02	1.15E+05	9.40E-04
U-236	8.87E+02	8.98E+02	9.96E+07	2.41E+04	3.78E+05	8.87E+02	4.20E+02	1.20E+07	9.55E-02
U-238	5.44E+02	6.54E+02	5.97E+07	1.55E+04	2.27E+05	6.13E+02	2.16E+04	7.18E+06	6.07E-02
Zr-93	1.24E+01	2.68E+01	7.36E+03	1.00E+05	1.24E+06	9.93E+00	3.44E+02	5.01E+04	6.03E-01

Nuclide	MAXIMUM BWR SUBMERSION DOSE RATE (rem-m^3/FA-s)**										MAR (Curies/FA)
	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Whole Body	Skin	Eye Lens	
H-3	0.00E+00	0.00E+00	1.79E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.16E-04	0.00E+00	0	1.76E+02
Kr-85	8.79E-01	1.01E+00	8.56E-01	8.19E-01	1.65E+00	8.86E-01	8.19E-01	8.94E-01	9.91E+01	0	2.03E+03
Totals:	8.79E-01	1.01E+00	8.58E-01	8.19E-01	1.65E+00	8.86E-01	8.19E-01	8.94E-01	9.91E+01	0.00E+00	

* Inhalation organ doses are cut/pasted from SR Source Terms.xls/Max PWR/BWR Dose

** Submersion organ doses are cut/pasted from SR Source Terms.xls/Submersion Dose

Crud Calculations

Fe-55 Included In Crud Calc. (Y/N):	Y
Crud Decay Time (years):	5

Fe-55 PWR Surface Activity (uCi/cm^2) =	1658.3	{values are corrected for half-life & avg surface activity if #
Fe-55 BWR Surface Activity (uCi/cm^2) =	2083.4	FA>1 (CRWMS M&O 1999d, Table 8-2)}
Co-60 PWR Surface Activity (uCi/cm^2) =	36.3	
Co-60 BWR Surface Activity (uCi/cm^2) =	324.9	
Bounding PWR Surface Area (cm^2) =	449,003	(CRWMS M&O 1999h, p. 25)
Bounding BWR Surface Area (cm^2) =	168,148	(CRWMS M&O 1999b, p. 46)

Conversions		Co-60 Half Life	Fe-55 Half Life
Bq per uCi =	3.70E+04	5.271 y	2.73 y
rem per Sv =	100		

Crud Source (Ci/FA)	
Fe-55 PWR	744.6
Fe-55 BWR	350.3
Co-60 PWR	16.3
Co-60 BWR	54.6

Yearly Class Dose Conversion Factors for Co-60 & Fe-55 (Sv/Bq)

(Eckerman et al. 1988, Table 2.1)

	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Whole Body
Co-60	4.76E-09	1.84E-08	3.45E-07	1.72E-08	1.35E-08	1.62E-08	3.60E-08	5.91E-08
Fe-55	1.79E-10	1.74E-10	1.06E-09	1.76E-10	1.75E-10	1.85E-10	4.37E-10	3.61E-10

Crud Inhalation Dose (rem/FA)

	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Whole Body
PWR Co-60	2.87E+05	1.11E+06	2.08E+07	1.04E+06	8.13E+05	9.76E+05	2.17E+06	3.56E+06
PWR Fe-55	4.93E+05	4.79E+05	2.92E+06	4.85E+05	4.82E+05	5.10E+05	1.20E+06	9.95E+05
BWR Co-60	9.62E+05	3.72E+06	6.97E+07	3.48E+06	2.73E+06	3.27E+06	7.28E+06	1.19E+07
BWR Fe-55	2.32E+05	2.26E+05	1.37E+06	2.28E+05	2.27E+05	2.40E+05	5.66E+05	4.68E+05

Source Term Groupings

PWR_DBF_10

		Maximum PWR Inhalation Dose (rem/FA)							
Group	Nuclide	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Whole Body
cs	Cs-134	1.79E+09	1.49E+09	1.62E+09	1.62E+09	1.51E+09	1.53E+09	1.91E+09	1.73E+09
cs	Cs-135	2.66E+03	2.66E+03	3.12E+03	2.66E+03	2.66E+03	2.66E+03	2.66E+03	2.72E+03
cs	Cs-137	3.20E+09	2.86E+09	3.22E+09	3.03E+09	2.90E+09	2.90E+09	3.33E+09	3.15E+09
g	H-3	3.02E+04	3.02E+04	3.02E+04	3.02E+04	3.02E+04	3.02E+04	3.02E+04	3.02E+04
g	I-129	1.09E+01	2.61E+01	Co-60 & Fe-5	1.75E+01	1.73E+01	1.95E+05	1.48E+01	5.87E+03
g	Kr-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
p	Ac-227	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
p	Am-241	1.05E+11	8.60E+06	5.93E+10	5.61E+11	6.99E+12	5.16E+06	2.52E+11	3.86E+11
p	Am-242m	1.21E+09	5.21E+04	1.59E+08	6.38E+09	8.00E+10	2.13E+04	2.82E+09	4.33E+09
p	Am-243	6.30E+09	2.94E+06	3.44E+09	3.34E+10	4.19E+11	1.60E+06	1.49E+10	2.31E+10
p	C-14	1.15E+01	1.15E+01	1.15E+01	1.15E+01	1.15E+01	1.15E+01	1.15E+01	1.15E+01
p	Cd-113m	6.67E+05	6.67E+05	5.78E+07	6.67E+05	6.67E+05	6.67E+05	2.63E+07	1.52E+07
P	Cl-36	1.81E+01	1.81E+01	1.63E+03	1.81E+01	1.81E+01	1.81E+01	1.92E+01	2.12E+02
P	Cm-242	7.23E+07	1.20E+05	1.97E+09	4.95E+08	6.18E+09	1.19E+05	3.11E+08	5.92E+08
P	Cm-243	2.93E+09	8.91E+05	2.75E+09	1.67E+10	2.08E+11	5.43E+05	8.16E+09	1.18E+10
P	Cm-244	6.59E+11	4.31E+07	8.00E+11	3.89E+12	4.85E+13	4.19E+07	1.98E+12	2.78E+12
P	Cm-245	1.76E+08	3.49E+04	9.39E+07	9.34E+08	1.17E+10	1.92E+04	4.15E+08	6.42E+08
P	Cm-246	1.04E+08	1.24E+04	5.64E+07	5.52E+08	6.88E+09	7.01E+03	2.46E+08	3.79E+08
P	Co-60	9.97E+07	3.85E+08	7.22E+09	3.60E+08	2.83E+08	3.39E+08	7.54E+08	1.24E+09
P	Eu-154	2.50E+08	3.31E+08	1.69E+09	2.26E+09	1.12E+10	1.52E+08	2.41E+09	1.65E+09
P	Eu-155	2.21E+06	3.82E+06	7.40E+07	8.89E+07	9.45E+08	1.49E+06	6.90E+07	6.98E+07
P	Fe-55	4.53E+05	4.40E+05	2.68E+06	4.45E+05	4.43E+05	4.68E+05	1.11E+06	9.14E+05
P	Nb-93m	2.60E+04	7.32E+03	1.08E+07	1.91E+04	4.77E+04	1.91E+03	5.11E+04	1.33E+06
p	Nb-94	2.08E+04	1.05E+05	3.51E+06	1.06E+05	9.26E+04	1.04E+05	2.09E+05	5.24E+05
p	Ni-59	1.12E+03	1.08E+03	1.23E+04	1.09E+03	1.08E+03	1.17E+03	1.44E+03	2.55E+03
p	Ni-63	3.80E+05	3.80E+05	4.73E+06	3.80E+05	3.80E+05	3.80E+05	5.65E+05	9.57E+05
p	Np-237	4.22E+07	2.41E+04	2.29E+07	3.73E+08	4.66E+09	1.91E+04	3.33E+07	2.08E+08
p	Pa-231	4.81E-01	8.88E-01	1.17E+05	4.53E+04	5.66E+05	7.00E-01	3.33E+01	3.65E+04
p	Pb-210	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
p	Pd-107	5.63E-02	5.63E-02	1.53E+04	3.05E-01	8.10E-01	5.63E-02	5.21E+01	1.85E+03
p	Pm-147	7.14E+02	3.12E+03	6.70E+09	1.39E+08	1.74E+09	1.71E+03	1.35E+08	9.14E+08
p	Pu-238	2.37E+11	1.00E+07	7.29E+12	1.32E+12	1.65E+13	8.80E+06	6.25E+11	1.78E+12
p	Pu-239	8.21E+09	2.73E+05	2.21E+11	4.50E+10	5.62E+11	2.57E+05	2.07E+10	5.70E+10
p	Pu-240	1.73E+10	6.25E+05	4.66E+11	9.48E+10	1.18E+12	5.43E+05	4.36E+10	1.20E+11
p	Pu-241	8.08E+10	6.26E+06	9.31E+11	4.19E+11	5.21E+12	2.68E+06	1.76E+11	3.91E+11
p	Pu-242	1.27E+08	4.84E+03	3.42E+09	6.96E+08	8.70E+09	4.13E+03	3.19E+08	8.82E+08
p	Ra-226	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
p	Ra-228	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
p	Ru-106	6.11E+07	8.36E+07	4.89E+10	8.27E+07	7.57E+07	8.08E+07	5.64E+08	6.08E+09
p	Sb-125	2.73E+06	3.16E+06	1.65E+08	4.06E+06	7.42E+06	2.46E+06	1.10E+07	2.50E+07
p	Se-79	1.54E+02	1.54E+02	2.52E+03	1.54E+02	1.54E+02	1.54E+02	9.69E+02	6.83E+02
p	Sm-147	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
p	Sm-151	4.67E+01	1.73E+02	3.78E+06	1.27E+07	1.60E+08	1.53E+01	8.70E+06	9.39E+06
p	Sn-126	1.15E+04	1.25E+04	3.51E+05	3.93E+04	7.74E+04	1.14E+04	2.79E+04	6.26E+04
p	Tc-99	1.89E+03	1.89E+03	7.91E+05	1.89E+03	1.89E+03	5.07E+04	2.96E+04	1.06E+05
p	Th-229	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
p	Th-230	2.27E+01	2.27E+01	3.95E+04	9.21E+03	1.15E+05	2.27E+01	5.90E+01	9.32E+03
p	Th-232	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
p	U-232	3.32E+03	5.23E+03	2.91E+08	9.19E+04	1.40E+06	4.77E+03	1.15E+05	3.50E+07
p	U-233	2.41E-01	2.44E-01	2.72E+04	6.62E+00	1.04E+02	2.42E-01	9.67E+00	3.27E+03
p	U-234	5.35E+03	5.41E+03	6.02E+08	1.46E+05	2.28E+06	5.35E+03	2.14E+05	7.24E+07
p	U-235	4.36E+01	8.25E+01	4.24E+06	1.10E+03	1.61E+04	6.31E+01	1.57E+03	5.10E+05
p	U-236	2.08E+03	2.11E+03	2.34E+08	5.66E+04	8.87E+05	2.08E+03	9.86E+02	2.81E+07
p	U-238	1.28E+03	1.54E+03	1.41E+08	3.64E+04	5.34E+05	1.44E+03	5.08E+04	1.69E+07
p	Zr-93	2.75E+01	5.91E+01	1.62E+04	2.21E+05	2.73E+06	2.19E+01	7.58E+02	1.10E+05
sr	Sr-90	6.15E+08	6.15E+08	8.69E+08	7.83E+10	1.69E+11	6.15E+08	7.83E+08	1.51E+10

Grouped Source Term - Maximum BWR

Group	Description	Inhalation Dose (rem/FA)							
		Gonad	Breast	Lung	R. Marrow	B. Surface	Thyroid	Remainder	Whole Body
p	Particulates	3.81E+11	2.13E+08	3.33E+12	2.18E+12	2.72E+13	1.44E+08	1.07E+12	1.90E+12
g	Noble Gases	1.13E+04	1.13E+04	1.13E+04	1.13E+04	1.13E+04	8.98E+04	1.13E+04	1.36E+04
cs	Cesium	1.81E+09	1.59E+09	1.77E+09	1.69E+09	1.61E+09	1.61E+09	1.90E+09	1.77E+09
sr	Strontium	2.46E+08	2.46E+08	3.48E+08	3.13E+10	6.78E+10	2.46E+08	3.13E+08	6.03E+09
c	Crud	1.19E+06	3.94E+06	7.11E+07	3.70E+06	2.96E+06	3.51E+06	7.84E+06	1.24E+07

CSNF Release Fractions in Air

Notes:	(1)	(2)	(3)	(4)	(5)	(6)
Nuclide	Cladding Damage Fraction (DF)	Airborne Release Fraction (ARF)	Local Dep. (DEP)	Clad Release Fraction (CR)	Respirable Fraction (RF)	Effective Release Fraction
H-3	1.0	0.3	1.0	1.0	1.0	3.00E-01
Kr-85	1.0	0.3	1.0	1.0	1.0	3.00E-01
I-129	1.0	0.3	1.0	1.0	1.0	3.00E-01
Cs	1.0	2.0E-04	1.0	1.0	1.0	2.00E-04
Sr	1.0	3.0E-05	1.0	1.0	5.0E-03	1.50E-07
Ru	1.0	3.0E-05	1.0	1.0	5.0E-03	1.50E-07
Crud	1.0	1.0E+00	1.0	1.0	3.0E-01	3.00E-01
Particulates	1.0	3.0E-05	1.0	1.0	5.0E-03	1.50E-07

CSNF Release Fractions in Water (Assumption 3.21)

Notes:	(1)	(2)	(3)	(4)	(5)	(6)
Nuclide	Cladding Damage Fraction (DF)	Airborne Release Fraction (ARF)	Local Dep. (DEP)	Clad Release Fraction (CR)	Respirable Fraction (RF)	Effective Release Fraction
H-3	1.0	0.3	1.0	1.0	1.0	0.3
Kr-85	1.0	0.3	1.0	1.0	1.0	0.3
I-129	1.0	0.3	1.0	1.0	1.0	0.3
Cs	1.0	0.0	1.0	1.0	1.0	0
Sr	1.0	0.0	1.0	1.0	1.0	0
Ru	1.0	0.0	1.0	1.0	1.0	0
Crud	1.0	0.0	1.0	1.0	1.0	0
Particulates	1.0	0.0	1.0	1.0	1.0	0

Notes:

(1) A fraction of 1.0 indicates that all the cladding is failed.

(2) ARFs in air are taken from Table 8-1 of CRWMS M&O (1999d); ARFs in water are based on Assumption 3.21.

(3) A factor of 1.0 indicates no local deposition.

(4) A factor of 1.0 indicates no retention in by the cladding.

(5) Respirable fractions are conservatively taken to be 1.0 for inhalation and ingestion (Assumption 3.24).

(6) Effective release fractions are obtained by multiplying columns (1) through (5)

X/Q Values/Interpolations

5,000-m Maximum Sector Acute X/Q (s/m^3)		
Distance (m)	99.5%	Reference
5,000	4.68E-05	CRWMS M&O (1999c), p. 11, Table 3, Sector 14

Application of X/Q

Cat. 2 DBE Release from WHB to Preclosure Controlled Area Boundary - Not used in this calculation

8,000-m Maximum Sector Acute X/Q (s/m^3)		
Distance (m)	99.5%	Reference
7,500	3.10E-05	CRWMS M&O (1999c), p. 11, Table 3, Sector 14
10,000	2.29E-05	CRWMS M&O (1999c), p. 11, Table 3, Sector 14
8,000	2.94E-05	Interpolated

Cat. 2 DBE Release from Subsurface to Land Withdrawal Boundary

11,000-m Maximum Sector Acute X/Q (s/m^3)		
Distance (m)	99.5%	Reference
10,000	2.29E-05	CRWMS M&O (1999c), p. 11, Table 3, Sector 14
20,000	1.08E-05	CRWMS M&O (1999c), p. 11, Table 3, Sector 14
11,000	2.17E-05	Interpolated

Cat. 2 DBE Release from WHB to Land Withdrawal Boundary

Submersion Dose (Due to Noble Gases H-3 and Kr-85)

Event: 2-09 Unsealed DC Drop and Slapdown

Fuel Type: Maximum BWR

(Column No.)	Maximum BWR Submersion Dose Rate (rem-m^3/FA-s) (1)	# of FA's (2)	Release Fraction (3)	Mitigation Factor (4)	X/Q (sec/m^3) (5)	Offsite Dose (rem) (6)=(1)*(2)*(3)*(4)*(5)
Gonad	8.79E-01	44	3.00E-01	1.00E+00	2.17E-05	2.52E-04
Breast	1.01E+00	44	3.00E-01	1.00E+00	2.17E-05	2.88E-04
Lung	8.58E-01	44	3.00E-01	1.00E+00	2.17E-05	2.46E-04
R Marrow	8.19E-01	44	3.00E-01	1.00E+00	2.17E-05	2.34E-04
B Surface	1.65E+00	44	3.00E-01	1.00E+00	2.17E-05	4.73E-04
Thyroid	8.86E-01	44	3.00E-01	1.00E+00	2.17E-05	2.54E-04
Remainder	8.19E-01	44	3.00E-01	1.00E+00	2.17E-05	2.34E-04
Whole Body	8.94E-01	44	3.00E-01	1.00E+00	2.17E-05	2.56E-04
Skin	9.91E+01	44	3.00E-01	1.00E+00	2.17E-05	2.84E-02
Eye Lens	0.00E+00	44	3.00E-01	1.00E+00	2.17E-05	0.00E+00

Inhalation Dose to the Gonad

Event: 2-09 Unsealed DC Drop and Slapdown
Fuel Type: Maximum BWR

Group	Source Term (rem/FA)	# of FA's	Release Fraction	Mitigation Factor	Breathing Rate (m^3/sec)	X/Q (sec/m^3)	Off-site Dose (rem)	% of Total
Particulates	3.81E+11	44	1.50E-07	1.0E-02	3.3E-04	2.17E-05	1.80E-04	5.13
Noble Gas	1.13E+04	44	3.00E-01	1.0E+00	3.3E-04	2.17E-05	1.06E-03	30.30
Cesium	1.81E+09	44	2.00E-04	1.0E-02	3.3E-04	2.17E-05	1.14E-03	32.48
Strontium	2.46E+08	44	1.50E-07	1.0E-02	3.3E-04	2.17E-05	1.16E-07	0.00
Crud	1.19E+06	44	3.00E-01	1.0E-02	3.3E-04	2.17E-05	1.13E-03	32.10
						Total:	3.51E-03	100.00

Inhalation Dose to the Breast

Event: 2-09 Unsealed DC Drop and Slapdown
Fuel Type: Maximum BWR

Group	Source Term (rem/FA)	# of FA's	Release Fraction	Mitigation Factor	Breathing Rate (m^3/sec)	X/Q (sec/m^3)	Off-site Dose (rem)	% of Total
Particulates	2.13E+08	44	1.50E-07	1.0E-02	3.3E-04	2.17E-05	1.00E-07	0.00
Noble Gas	1.13E+04	44	3.00E-01	1.0E+00	3.3E-04	2.17E-05	1.07E-03	18.40
Cesium	1.59E+09	44	2.00E-04	1.0E-02	3.3E-04	2.17E-05	9.99E-04	17.25
Strontium	2.46E+08	44	1.50E-07	1.0E-02	3.3E-04	2.17E-05	1.16E-07	0.00
Crud	3.94E+06	44	3.00E-01	1.0E-02	3.3E-04	2.17E-05	3.73E-03	64.35
						Total:	5.79E-03	100.00

Inhalation Dose to the Lung

Event: 2-09 Unsealed DC Drop and Slapdown
Fuel Type: Maximum BWR

Group	Source Term (rem/FA)	# of FA's	Release Fraction	Mitigation Factor	Breathing Rate (m^3/sec)	X/Q (sec/m^3)	Off-site Dose (rem)	% of Total
Particulates	3.33E+12	44	1.50E-07	1.0E-02	3.3E-04	2.17E-05	1.57E-03	2.21
Noble Gas	1.13E+04	44	3.00E-01	1.0E+00	3.3E-04	2.17E-05	1.07E-03	1.50
Cesium	1.77E+09	44	2.00E-04	1.0E-02	3.3E-04	2.17E-05	1.11E-03	1.57
Strontium	3.48E+08	44	1.50E-07	1.0E-02	3.3E-04	2.17E-05	1.64E-07	0.00
Crud	7.11E+07	44	3.00E-01	1.0E-02	3.3E-04	2.17E-05	6.72E-02	94.71
						Total:	7.09E-02	100.00

Inhalation Dose to the R Marrow

Event: 2-09 Unsealed DC Drop and Slapdown
Fuel Type: Maximum BWR

Group	Source Term (rem/FA)	# of FA's	Release Fraction	Mitigation Factor	Breathing Rate (m^3/sec)	X/Q (sec/m^3)	Off-site Dose (rem)	% of Total
Particulates	2.18E+12	44	1.50E-07	1.0E-02	3.3E-04	2.17E-05	1.03E-03	15.45
Noble Gas	1.13E+04	44	3.00E-01	1.0E+00	3.3E-04	2.17E-05	1.07E-03	15.95
Cesium	1.69E+09	44	2.00E-04	1.0E-02	3.3E-04	2.17E-05	1.07E-03	15.98
Strontium	3.13E+10	44	1.50E-07	1.0E-02	3.3E-04	2.17E-05	1.48E-05	0.22
Crud	3.70E+06	44	3.00E-01	1.0E-02	3.3E-04	2.17E-05	3.50E-03	52.40
					Total		6.68E-03	100.00

Inhalation Dose to the Bone Surface

Event: 2-09 Unsealed DC Drop and Slapdown
Fuel Type: Maximum BWR

Group	Source Term (rem/FA)	# of FA's	Release Fraction	Mitigation Factor	Breathing Rate (m^3/sec)	X/Q (sec/m^3)	Off-site Dose (rem)	% of Total
Particulates	2.72E+13	44	1.50E-07	1.0E-02	3.3E-04	2.17E-05	1.29E-02	72.42
Noble Gas	1.13E+04	44	3.00E-01	1.0E+00	3.3E-04	2.17E-05	1.07E-03	5.99
Cesium	1.61E+09	44	2.00E-04	1.0E-02	3.3E-04	2.17E-05	1.01E-03	5.70
Strontium	6.78E+10	44	1.50E-07	1.0E-02	3.3E-04	2.17E-05	3.20E-05	0.18
Crud	2.96E+06	44	3.00E-01	1.0E-02	3.3E-04	2.17E-05	2.79E-03	15.71
					Total		1.78E-02	100.00

Inhalation Dose to the Thyroid

Event: 2-09 Unsealed DC Drop and Slapdown
Fuel Type: Maximum BWR

Group	Source Term (rem/FA)	# of FA's	Release Fraction	Mitigation Factor	Breathing Rate (m^3/sec)	X/Q (sec/m^3)	Off-site Dose (rem)	% of Total
Particulates	1.44E+08	44	1.50E-07	1.0E-02	3.3E-04	2.17E-05	6.79E-08	0.00
Noble Gas	8.98E+04	44	3.00E-01	1.0E+00	3.3E-04	2.17E-05	8.48E-03	66.17
Cesium	1.61E+09	44	2.00E-04	1.0E-02	3.3E-04	2.17E-05	1.02E-03	7.92
Strontium	2.46E+08	44	1.50E-07	1.0E-02	3.3E-04	2.17E-05	1.16E-07	0.00
Crud	3.51E+06	44	3.00E-01	1.0E-02	3.3E-04	2.17E-05	3.32E-03	25.91
					Total		1.28E-02	100.00

Inhalation Dose to the Remainder

Event: 2-09 Unsealed DC Drop and Slapdown
Fuel Type: Maximum BWR

Group	Source Term (rem/FA)	# of FA's	Release Fraction	Mitigation Factor	Breathing Rate (m^3/sec)	X/Q (sec/m^3)	Off-site Dose (rem)	% of Total
Particulates	1.07E+12	44	1.50E-07	1.0E-02	3.3E-04	2.17E-05	5.07E-04	4.98
Noble Gas	1.13E+04	44	3.00E-01	1.0E+00	3.3E-04	2.17E-05	1.06E-03	10.46
Cesium	1.90E+09	44	2.00E-04	1.0E-02	3.3E-04	2.17E-05	1.20E-03	11.77
Strontium	3.13E+08	44	1.50E-07	1.0E-02	3.3E-04	2.17E-05	1.48E-07	0.00
Crud	7.84E+06	44	3.00E-01	1.0E-02	3.3E-04	2.17E-05	7.41E-03	72.79
					Total		1.02E-02	100.00

Inhalation Dose to the Whole Body

Event: 2-09 Unsealed DC Drop and Slapdown
Fuel Type: Maximum BWR

Group	Source Term (rem/FA)	# of FA's	Release Fraction	Mitigation Factor	Breathing Rate (m^3/sec)	X/Q (sec/m^3)	Off-site Dose (rem)	% of Total
Particulates	1.90E+12	44	1.50E-07	1.0E-02	3.3E-04	2.17E-05	8.96E-04	5.96
Noble Gas	1.36E+04	44	3.00E-01	1.0E+00	3.3E-04	2.17E-05	1.29E-03	8.57
Cesium	1.77E+09	44	2.00E-04	1.0E-02	3.3E-04	2.17E-05	1.12E-03	7.43
Strontium	6.03E+09	44	1.50E-07	1.0E-02	3.3E-04	2.17E-05	2.85E-06	0.02
Crud	1.24E+07	44	3.00E-01	1.0E-02	3.3E-04	2.17E-05	1.17E-02	78.02
					Total		1.50E-02	100.00

Input Parameters for Category 2 Dose Calculations:

Fuel Type:		
Average PWR Average BWR Maximum PWR Maximum BWR	Maximum PWR	
Event #:	2-01	
Event Description:	Basket Collision During Transfer to Pool Storage	
Location:	ATS Pool	
Event Frequency:	6.83E-03	
Number of Fuel Assemblies Damaged:	4	(Note 1)
Does the Event Occur in a Pool?	Yes No	
HEPA Mitigation Factor:		
HEPA Filtration	0.01	Particulate Release (Note 3)
No HEPA Filtration	1.0	Gas Release (Note 3)
99.5% Acute X/Q: Distance (m):		
5,000 8,000 11,000	2.17E-05	(Note 2)
Breathing Rate (m^3/sec)	3.3E-04	(Note 4)
Ground Release?	Y	(Note 5)

Note 1: Number of fuel assemblies determined according to assumption 3.19.

Note 2: Acute releases are assumed for all Cat. 2 calculations. See "X-Q Values" worksheet for X/Q details.

Note 3: HEPA filters, if available, are 99% effective in retaining particulates and volatiles (Cs) (Assumption 3.23). 100% of the Noble gases are released.

Note 4: Breathing rate based on Standard Review Plan for Dry Cask Storage Systems, NUREG-1536. Based on acute exposures to "reference man."

Note 5: Ground release is conservatively assumed for Cat. 2 calculations; using a stack release will typically result in a lower offsite dose (Assumption 3.25).

Blue shading = calculated fields

Yellow shading = input fields

Input Parameters for Category 2 Dose Calculations:

Fuel Type:		
Average PWR / Average BWR / **Maximum PWR** / Maximum BWR	Maximum PWR	
Event #:	2-02	
Event Description:	Basket Collision During Transfer to Incline Transfer Canal	
Location:	ATS Pool	
Event Frequency:	6.83E-03	
Number of Fuel Assemblies Damaged:	4	(Note 1)
Does the Event Occur in a Pool?	**Yes** / No	
HEPA Mitigation Factor:		
HEPA Filtration	0.01	Particulate Release (Note 3)
No HEPA Filtration	1.0	Gas Release (Note 3)
99.5% Acute X/Q: Distance (m):		
5,000 / 8,000 / **11,000**	2.17E-05	(Note 2)
Breathing Rate (m^3/sec)	3.3E-04	(Note 4)
Ground Release?	Y	(Note 5)

Note 1: Number of fuel assemblies determined according to assumption 3.19.

Note 2: Acute releases are assumed for all Cat. 2 calculations. See "X-Q Values" worksheet for X/Q details.

Note 3: HEPA filters, if available, are 99% effective in retaining particulates and volatiles (Cs) (Assumption 3.23). 100% of the Noble gases are released.

Note 4: Breathing rate based on Standard Review Plan for Dry Cask Storage Systems, NUREG-1536. Based on acute exposures to "reference man."

Note 5: Ground release is conservatively assumed for Cat. 2 calculations; using a stack release will typically result in a lower offsite dose (Assumption 3.25).

Blue shading = calculated fields

Yellow shading = input fields

Input Parameters for Category 2 Dose Calculations:

Fuel Type:		
Average PWR / Average BWR / **Maximum PWR** / Maximum BWR	Maximum PWR	
Event #:	2-03	
Event Description:	Uncontrolled Descent of Incline Transfer Cart	
Location:	ATS Pool	
Event Frequency:	6.83E-03	
Number of Fuel Assemblies Damaged:	4	(Note 1)
Does the Event Occur in a Pool?	**Yes** / No	
HEPA Mitigation Factor:		
HEPA Filtration / No HEPA Filtration	0.01	Particulate Release (Note 3)
	1.0	Gas Release (Note 3)
99.5% Acute X/Q: Distance (m):		
5,000 / 8,000 / **11,000**	2.17E-05	(Note 2)
Breathing Rate (m^3/sec)	3.3E-04	(Note 4)
Ground Release?	Y	(Note 5)

Note 1: Number of fuel assemblies determined according to assumption 3.19.

Note 2: Acute releases are assumed for all Cat. 2 calculations. See "X-Q Values" worksheet for X/Q details.

Note 3: HEPA filters, if available, are 99% effective in retaining particulates and volatiles (Cs) (Assumption 3.23). 100% of the Noble gases are released.

Note 4: Breathing rate based on Standard Review Plan for Dry Cask Storage Systems, NUREG-1536. Based on acute exposures to "reference man."

Note 5: Ground release is conservatively assumed for Cat. 2 calculations; using a stack release will typically result in a lower offsite dose (Assumption 3.25).

Blue shading = calculated fields

Yellow shading = input fields

Input Parameters for Category 2 Dose Calculations:

Fuel Type:	Maximum PWR	
Event #:	2-04	
Event Description:	Handling Equipment Drop Onto SFA in Pool	
Location:	ATS Pool	
Event Frequency:	2.38E-03	
Number of Fuel Assemblies Damaged:	1	(Note 1)
Does the Event Occur in a Pool?	Yes	
HEPA Mitigation Factor:	0.01	Particulate Release (Note 3)
	1.0	Gas Release (Note 3)
99.5% Acute X/Q: Distance (m):	2.17E-05	(Note 2)
Breathing Rate (m^3/sec)	3.3E-04	(Note 4)
Ground Release?	Y	(Note 5)

Note 1: Number of fuel assemblies determined according to assumption 3.19.

Note 2: Acute releases are assumed for all Cat. 2 calculations. See "X-Q Values" worksheet for X/Q details.

Note 3: HEPA filters, if available, are 99% effective in retaining particulates and volatiles (Cs) (Assumption 3.23). 100% of the Noble gases are released.

Note 4: Breathing rate based on Standard Review Plan for Dry Cask Storage Systems, NUREG-1536. Based on acute exposures to "reference man."

Note 5: Ground release is conservatively assumed for Cat. 2 calculations; using a stack release will typically result in a lower offsite dose (Assumption 3.25).

Blue shading = calculated fields

Yellow shading = input fields

Input Parameters for Category 2 Dose Calculations:

Fuel Type:	Maximum PWR	
Event #:	2-05	
Event Description:	Handling Equipment Drop Onto SFA in Hot Cell	
Location:	ATS Hot Cell	
Event Frequency:	2.38E-03	
Number of Fuel Assemblies Damaged:	1	(Note 1)
Does the Event Occur in a Pool?	No	
HEPA Mitigation Factor:	0.01	Particulate Release (Note 3)
	1.0	Gas Release (Note 3)
99.5% Acute X/Q: Distance (m):	11,000	
	2.17E-05	(Note 2)
Breathing Rate (m^3/sec)	3.3E-04	(Note 4)
Ground Release?	Y	(Note 5)

Note 1: Number of fuel assemblies determined according to assumption 3.19.

Note 2: Acute releases are assumed for all Cat. 2 calculations. See "X-Q Values" worksheet for X/Q details.

Note 3: HEPA filters, if available, are 99% effective in retaining particulates and volatiles (Cs) (Assumption 3.23). 100% of the Noble gases are released.

Note 4: Breathing rate based on Standard Review Plan for Dry Cask Storage Systems, NUREG-1536. Based on acute exposures to "reference man."

Note 5: Ground release is conservatively assumed for Cat. 2 calculations; using a stack release will typically result in a lower offsite dose (Assumption 3.25).

Blue shading = calculated fields

Yellow shading = input fields

Input Parameters for Category 2 Dose Calculations:

Fuel Type:	Maximum PWR	
Event #:	2-06	
Event Description:	Handling Equipment Drop Onto SFA Basket in Pool	
Location:	ATS Pool	
Event Frequency:	1.74E-03	
Number of Fuel Assemblies Damaged:	4	(Note 1)
Does the Event Occur in a Pool?	Yes	
HEPA Mitigation Factor:	0.01	Particulate Release (Note 3)
	1.0	Gas Release (Note 3)
99.5% Acute X/Q Distance (m):	2.17E-05	(Note 2)
Breathing Rate (m^3/sec)	3.3E-04	(Note 4)
Ground Release?	Y	(Note 5)

Note 1: Number of fuel assemblies determined according to assumption 3.19.

Note 2: Acute releases are assumed for all Cat. 2 calculations. See "X-Q Values" worksheet for X/Q details.

Note 3: HEPA filters, if available, are 99% effective in retaining particulates and volatiles (Cs) (Assumption 3.23). 100% of the Noble gases are released.

Note 4: Breathing rate based on Standard Review Plan for Dry Cask Storage Systems, NUREG-1536. Based on acute exposures to "reference man."

Note 5: Ground release is conservatively assumed for Cat. 2 calculations; using a stack release will typically result in a lower offsite dose (Assumption 3.25).

Blue shading = calculated fields

Yellow shading = input fields

Input Parameters for Category 2 Dose Calculations:

Fuel Type:	Maximum BWR	
Event #:	2-07	
Event Description:	Handling Equipment Drop Onto SFA Basket in Hot Cell	
Location:	ATS Hot Cell	
Event Frequency:	6.95E-05	
Number of Fuel Assemblies Damaged:	8	(Note 1)
Does the Event Occur in a Pool?	No	
HEPA Mitigation Factor:		
HEPA Filtration	0.01	Particulate Release (Note 3)
No HEPA Filtration	1.0	Gas Release (Note 3)
99.5% Acute X/Q Distance (m):		
11,000	2.17E-05	(Note 2)
Breathing Rate (m^3/sec)	3.3E-04	(Note 4)
Ground Release?	Y	(Note 5)

Note 1: Number of fuel assemblies determined according to assumption 3.19.

Note 2: Acute releases are assumed for all Cat. 2 calculations. See "X-Q Values" worksheet for X/Q details.

Note 3: HEPA filters, if available, are 99% effective in retaining particulates and volatiles (Cs) (Assumption 3.23). 100% of the Noble gases are released.

Note 4: Breathing rate based on Standard Review Plan for Dry Cask Storage Systems, NUREG-1536. Based on acute exposures to "reference man."

Note 5: Ground release is conservatively assumed for Cat. 2 calculations; using a stack release will typically result in a lower offsite dose (Assumption 3.25).

Blue shading = calculated fields

Yellow shading = input fields

Input Parameters for Category 2 Dose Calculations:

Fuel Type:	Maximum BWR	
Event #:	2-08	
Event Description:	Unsealed DC Collision	
Location:	DC Handling Cell	
Event Frequency:	1.80E-03	
Number of Fuel Assemblies Damaged:	44	(Note 1)
Does the Event Occur in a Pool?	No	
HEPA Mitigation Factor:		
HEPA Filtration	0.01	Particulate Release (Note 3)
No HEPA Filtration	1.0	Gas Release (Note 3)
99.5% Acute X/Q: Distance (m):		
11,000	2.17E-05	(Note 2)
Breathing Rate (m^3/sec)	3.3E-04	(Note 4)
Ground Release?	Y	(Note 5)

Note 1: Number of fuel assemblies determined according to assumption 3.19.

Note 2: Acute releases are assumed for all Cat. 2 calculations. See "X-Q Values" worksheet for X/Q details.

Note 3: HEPA filters, if available, are 99% effective in retaining particulates and volatiles (Cs) (Assumption 3.23). 100% of the Noble gases are released.

Note 4: Breathing rate based on Standard Review Plan for Dry Cask Storage Systems, NUREG-1536. Based on acute exposures to "reference man."

Note 5: Ground release is conservatively assumed for Cat. 2 calculations; using a stack release will typically result in a lower offsite dose (Assumption 3.25).

Blue shading = calculated fields

Yellow shading = input fields

Input Parameters for Category 2 Dose Calculations:

Fuel Type:	Maximum BWR	
Event #:	2-09	
Event Description:	Unsealed DC Drop and Slapdown	
Location:	DC Handling Cell	
Event Frequency:	8.40E-03	
Number of Fuel Assemblies Damaged:	44	(Note 1)
Does the Event Occur in a Pool?	No	
HEPA Mitigation Factor:	0.01	Particulate Release (Note 3)
	1.0	Gas Release (Note 3)
99.5% Acute X/Q: Distance (m): 11,000	2.17E-05	(Note 2)
Breathing Rate (m^3/sec)	3.3E-04	(Note 4)
Ground Release?	Y	(Note 5)

Note 1: Number of fuel assemblies determined according to assumption 3.19.

Note 2: Acute releases are assumed for all Cat. 2 calculations. See "X-Q Values" worksheet for X/Q details.

Note 3: HEPA filters, if available, are 99% effective in retaining particulates and volatiles (Cs) (Assumption 3.23). 100% of the Noble gases are released.

Note 4: Breathing rate based on Standard Review Plan for Dry Cask Storage Systems, NUREG-1536. Based on acute exposures to "reference man."

Note 5: Ground release is conservatively assumed for Cat. 2 calculations; using a stack release will typically result in a lower offsite dose (Assumption 3.25).

Blue shading = calculated fields

Yellow shading = input fields

Input Parameters for Category 2 Dose Calculations:

Fuel Type:	Maximum BWR	
Event #:	2-10	
Event Description:	Handling Equipment Drop Onto Unsealed DC	
Location:	DC Handling Cell	
Event Frequency:	1.10E-04	
Number of Fuel Assemblies Damaged:	44	(Note 1)
Does the Event Occur in a Pool?	No	
HEPA Mitigation Factor:		
HEPA Filtration	0.01	Particulate Release (Note 3)
No HEPA Filtration	1.0	Gas Release (Note 3)
99.5% Acute X/Q: Distance (m):		
11,000	2.17E-05	(Note 2)
Breathing Rate (m^3/sec)	3.3E-04	(Note 4)
Ground Release?	Y	(Note 5)

Note 1: Number of fuel assemblies determined according to assumption 3.19.

Note 2: Acute releases are assumed for all Cat. 2 calculations. See "X-Q Values" worksheet for X/Q details.

Note 3: HEPA filters, if available, are 99% effective in retaining particulates and volatiles (Cs) (Assumption 3.23). 100% of the Noble gases are released.

Note 4: Breathing rate based on Standard Review Plan for Dry Cask Storage Systems, NUREG-1536. Based on acute exposures to "reference man."

Note 5: Ground release is conservatively assumed for Cat. 2 calculations; using a stack release will typically result in a lower offsite dose (Assumption 3.25).

Blue shading = calculated fields

Yellow shading = input fields

Input Parameters for Category 2 Dose Calculations:

Fuel Type:	Maximum BWR	
Event #:	2-11	
Event Description:	Shipping Cask Drop Into Cask Preparation Pit	
Location:	ATS Cask Preparation Pit	
Event Frequency:	8.68E-03	
Number of Fuel Assemblies Damaged:	68	(Note 1)
Does the Event Occur in a Pool?	No	
HEPA Mitigation Factor:		
HEPA Filtration	0.01	Particulate Release (Note 3)
No HEPA Filtration	1.0	Gas Release (Note 3)
99.5% Acute X/Q: Distance (m):		
11,000	2.17E-05	(Note 2)
Breathing Rate (m^3/sec)	3.3E-04	(Note 4)
Ground Release?	Y	(Note 5)

Note 1: Number of fuel assemblies determined according to assumption 3.19.

Note 2: Acute releases are assumed for all Cat. 2 calculations. See "X-Q Values" worksheet for X/Q details.

Note 3: HEPA filters, if available, are 99% effective in retaining particulates and volatiles (Cs) (Assumption 3.23). 100% of the Noble gases are released.

Note 4: Breathing rate based on Standard Review Plan for Dry Cask Storage Systems, NUREG-1536. Based on acute exposures to "reference man."

Note 5: Ground release is conservatively assumed for Cat. 2 calculations; using a stack release will typically result in a lower offsite dose (Assumption 3.25).

Blue shading = calculated fields

Yellow shading = input fields

Input Parameters for Category 2 Dose Calculations:

Fuel Type:	Maximum BWR	
Event #:	2-12	
Event Description:	Shipping Cask Drop Into Cask Unloading Pool	
Location:	ATS Pool	
Event Frequency:	8.68E-03	
Number of Fuel Assemblies Damaged:	68	(Note 1)
Does the Event Occur in a Pool?	Yes	
HEPA Mitigation Factor:	0.01	Particulate Release (Note 3)
	1.0	Gas Release (Note 3)
99.5% Acute X/Q: Distance (m): 11,000	2.17E-05	(Note 2)
Breathing Rate (m^3/sec)	3.3E-04	(Note 4)
Ground Release?	Y	(Note 5)

Note 1: Number of fuel assemblies determined according to assumption 3.19.

Note 2: Acute releases are assumed for all Cat. 2 calculations. See "X-Q Values" worksheet for X/Q details.

Note 3: HEPA filters, if available, are 99% effective in retaining particulates and volatiles (Cs) (Assumption 3.23). 100% of the Noble gases are released.

Note 4: Breathing rate based on Standard Review Plan for Dry Cask Storage Systems, NUREG-1536. Based on acute exposures to "reference man."

Note 5: Ground release is conservatively assumed for Cat. 2 calculations; using a stack release will typically result in a lower offsite dose (Assumption 3.25).

Blue shading = calculated fields

Yellow shading = input fields

Input Parameters for Category 2 Dose Calculations:

Fuel Type:		
Average PWR Average BWR Maximum PWR **Maximum BWR**	Maximum BWR	
Event #:	NM-01	
Event Description:	Non-Mechanistic Shipping Cask Leak	
Location:	Carrier Bay	
Event Frequency:	NM	(Note 6)
Number of Fuel Assemblies Damaged:	68	(Note 1)
Gas Release Only?	**Yes** No	
HEPA Mitigation Factor:		
HEPA Filtration	1.00	Particulate Release (Note 3)
No HEPA Filtration	1.0	Gas Release (Note 3)
99.5% Acute X/Q: Distance (m):		
5,000 8,000 **11,000**	2.17E-05	(Note 2)
Breathing Rate (m^3/sec)	3.3E-04	(Note 4)
Ground Release?	Y	(Note 5)

Note 1: Number of fuel assemblies determined according to assumption 3.19.

Note 2: Acute releases are assumed for all Cat. 2 calculations. See "X-Q Values" worksheet for X/Q details.

Note 3: HEPA filters, if available, are 99% effective in retaining particulates and volatiles (Cs) (Assumption 3.23). 100% of the Noble gases are released.

Note 4: Breathing rate based on Standard Review Plan for Dry Cask Storage Systems, NUREG-1536. Based on acute exposures to "reference man."

Note 5: Ground release is conservatively assumed for Cat. 2 calculations; using a stack release will typically result in a lower offsite dose (Assumption 3.25).

Note 6: A non-mechanistic release was assumed without a frequency analysis. Sealed cask and WP breaches are assumed to be beyond design basis events (Assumption 3.15).

Blue shading = calculated fields

Yellow shading = input fields

Input Parameters for Category 2 Dose Calculations:

Fuel Type:	Maximum PWR	
Event #:	NM-02	
Event Description:	Non-Mechanistic Preclosure Early Failure of a WP	
Location:	Subsurface	
Event Frequency:	NM	(Note 6)
Number of Fuel Assemblies Damaged:	21	(Note 1)
Gas Release Only?	Yes	
HEPA Mitigation Factor:	1.00	Particulate Release (Note 3)
	1.0	Gas Release (Note 3)
99.5% Acute X/Q Distance (m):	2.94E-05	(Note 2)
Breathing Rate (m^3/sec)	3.3E-04	(Note 4)
Ground Release?	Y	(Note 5)

Note 1: Number of fuel assemblies determined according to assumption 3.19.

Note 2: Acute releases are assumed for all Cat. 2 calculations. See "X-Q Values" worksheet for X/Q details.

Note 3: HEPA filters, if available, are 99% effective in retaining particulates and volatiles (Cs) (Assumption 3.23). 100% of the Noble gases are released.

Note 4: Breathing rate based on Standard Review Plan for Dry Cask Storage Systems, NUREG-1536. Based on acute exposures to "reference man."

Note 5: Ground release is conservatively assumed for Cat. 2 calculations; using a stack release will typically result in a lower offsite dose (Assumption 3.25).

Note 6: A non-mechanistic release was assumed without a frequency analysis. Sealed cask and WP breaches are assumed to be beyond design basis events (Assumption 3.15).

Blue shading = calculated fields

Yellow shading = input fields

Summary of Inhalation and Submersion Dose Calculations

Event: **2-01** **Basket Collision During Transfer to Pool Storage**

Fuel Type: Maximum PWR

Organ	Inhalation Dose (rem)	Dose Term for Regulation	Submersion Dose (rem)	Dose Term for Regulation	Sum of Inhalation and Submersion (rem)	Dose Term for Regulation
Gonad	2.60E-04		6.34E-05		3.23E-04	
Breast	2.60E-04		7.27E-05		3.32E-04	
Lung	2.60E-04		6.19E-05		3.21E-04	
R Marrow	2.60E-04		01-Feb		3.69E+04	
B Surface	2.60E-04		1.19E-04		3.79E-04	
Thyroid	1.94E-03	<MAX CDE	6.40E-05		2.00E-03	
Remainder	2.60E-04		5.91E-05		3.19E-04	
Whole Body	**3.10E-04**	<CEDE	**6.45E-05**	<DDE	**3.74E-04**	<TEDE=CEDE+DDE
Eye Lens	N/A		0.00E+00	<EYE		
Skin	N/A		7.16E-03	<SKIN		
					2.00E-03	<MAX CDE + DDE

The maximum organ inhalation dose (CDE) is to the Thyroid

Note: Bolded results are added together to calculate TEDE (CEDE + DDE)

RESULTS:

Dose Term	Offsite Dose (rem)
TEDE =	3.74E-04
Max. CDE + DDE =	2.00E-03
Eye =	0.00E+00
Skin =	7.16E-03

Dose Terms:
TEDE = total effective dose equivalent
CEDE = inhalation whole body
DDE = submersion whole body
CDE = maximum internal organ, inhalation

Summary of Inhalation and Submersion Dose Calculations

Event: **2-02** **Basket Collision During Transfer to Incline Transfer Canal**

Fuel Type: Maximum PWR

Organ	Inhalation Dose (rem)	Dose Term for Regulation	Submersion Dose (rem)	Dose Term for Regulation	Sum of Inhalation and Submersion (rem)	Dose Term for Regulation
Gonad	2.60E-04		6.34E-05		3.23E-04	
Breast	2.60E-04		7.27E-05		3.32E-04	
Lung	2.60E-04		6.19E-05		3.21E-04	
R Marrow	2.60E-04		01-Feb		3.69E+04	
B Surface	2.60E-04		1.19E-04		3.79E-04	
Thyroid	1.94E-03	<MAX CDE	6.40E-05		2.00E-03	
Remainder	2.60E-04		5.91E-05		3.19E-04	
Whole Body	**3.10E-04**	<CEDE	**6.45E-05**	<DDE	**3.74E-04**	<TEDE=CEDE+DDE
Eye Lens	N/A		0.00E+00	<EYE		
Skin	N/A		7.16E-03	<SKIN		
					2.00E-03	<MAX CDE + DDE

The maximum organ inhalation dose (CDE) is to the Thyroid

Note: Bolded results are added together to calculate TEDE (CEDE + DDE)

RESULTS:

Dose Term	Offsite Dose (rem)
TEDE =	3.74E-04
Max. CDE + DDE =	2.00E-03
Eye =	0.00E+00
Skin =	7.16E-03

Dose Terms:
TEDE = total effective dose equivalent
CEDE = inhalation whole body
DDE = submersion whole body
CDE = maximum internal organ, inhalation

Summary of Inhalation and Submersion Dose Calculations

Event: **2-03** **Uncontrolled Descent of Incline Transfer Cart**

Fuel Type: Maximum PWR

Organ	Inhalation Dose (rem)	Dose Term for Regulation	Submersion Dose (rem)	Dose Term for Regulation	Sum of Inhalation and Submersion (rem)	Dose Term for Regulation
Gonad	2.60E-04		6.34E-05		3.23E-04	
Breast	2.60E-04		7.27E-05		3.32E-04	
Lung	2.60E-04		6.19E-05		3.21E-04	
R Marrow	2.60E-04		01-Feb		3.69E+04	
B Surface	2.60E-04		1.19E-04		3.79E-04	
Thyroid	1.94E-03	<MAX CDE	6.40E-05		2.00E-03	
Remainder	2.60E-04		5.91E-05		3.19E-04	
Whole Body	**3.10E-04**	<CEDE	**6.45E-05**	<DDE	**3.74E-04**	<TEDE=CEDE+DDE
Eye Lens	N/A		0.00E+00	<EYE		
Skin	N/A		7.16E-03	<SKIN		
					2.00E-03	<MAX CDE + DDE

The maximum organ inhalation dose (CDE) is to the Thyroid

Note: Bolded results are added together to calculate TEDE (CEDE + DDE)

RESULTS:

Dose Term	Offsite Dose (rem)
TEDE =	3.74E-04
Max. CDE + DDE =	2.00E-03
Eye =	0.00E+00
Skin =	7.16E-03

Dose Terms:
TEDE = total effective dose equivalent
CEDE = inhalation whole body
DDE = submersion whole body
CDE = maximum internal organ, inhalation

Summary of Inhalation and Submersion Dose Calculations

Event: **2-04** **Handling Equipment Drop Onto SFA in Pool**

Fuel Type: Maximum PWR

Organ	Inhalation Dose (rem)	Dose Term for Regulation	Submersion Dose (rem)	Dose Term for Regulation	Sum of Inhalation and Submersion (rem)	Dose Term for Regulation
Gonad	6.49E-05		1.59E-05		8.08E-05	
Breast	6.49E-05		1.82E-05		8.31E-05	
Lung	6.49E-05		1.55E-05		8.04E-05	
R Marrow	6.49E-05		01-Feb		3.69E+04	
B Surface	6.49E-05		2.98E-05		9.47E-05	
Thyroid	4.84E-04	<MAX CDE	1.60E-05		5.00E-04	
Remainder	6.49E-05		1.48E-05		7.97E-05	
Whole Body	**7.75E-05**	<CEDE	**1.61E-05**	<DDE	**9.36E-05**	<TEDE=CEDE+DDE
Eye Lens	N/A		0.00E+00	<EYE		
Skin	N/A		1.79E-03	<SKIN		
					5.00E-04	<MAX CDE + DDE

The maximum organ inhalation dose (CDE) is to the Thyroid

Note: Bolded results are added together to calculate TEDE (CEDE + DDE)

RESULTS:

Dose Term	Offsite Dose (rem)
TEDE =	9.36E-05
Max. CDE + DDE =	5.00E-04
Eye =	0.00E+00
Skin =	1.79E-03

Dose Terms:
TEDE = total effective dose equivalent
CEDE = inhalation whole body
DDE = submersion whole body
CDE = maximum internal organ, inhalation

Summary of Inhalation and Submersion Dose Calculations

Event: **2-05** **Handling Equipment Drop Onto SFA in Hot Cell**

Fuel Type: Maximum PWR

Organ	Inhalation Dose (rem)	Dose Term for Regulation	Submersion Dose (rem)	Dose Term for Regulation	Sum of Inhalation and Submersion (rem)	Dose Term for Regulation
Gonad	1.95E-04		1.59E-05		2.10E-04	
Breast	2.92E-04		1.82E-05		3.10E-04	
Lung	3.26E-03	<MAX CDE	1.55E-05		3.28E-03	<MAX CDE
R Marrow	3.55E-04		01-Feb		3.69E+04	
B Surface	1.11E-03		2.98E-05		1.14E-03	
Thyroid	6.93E-04		1.60E-05		7.09E-04	
Remainder	4.98E-04		1.48E-05		5.13E-04	
Whole Body	**7.30E-04**	<CEDE	**1.61E-05**	<DDE	**7.46E-04**	<TEDE=CEDE+DDE
Eye Lens	N/A		0.00E+00	<EYE		
Skin	N/A		1.79E-03	<SKIN		
					3.28E-03	<MAX CDE + DDE

The maximum organ inhalation dose (CDE) is to the Thyroid

Note: Bolded results are added together to calculate TEDE (CEDE + DDE)

RESULTS:

Dose Term	Offsite Dose (rem)
TEDE =	7.46E-04
Max. CDE + DDE =	3.28E-03
Eye =	0.00E+00
Skin =	1.79E-03

Dose Terms:
TEDE = total effective dose equivalent
CEDE = inhalation whole body
DDE = submersion whole body
CDE = maximum internal organ, inhalation

Summary of Inhalation and Submersion Dose Calculations

Event: **2-06** **Handling Equipment Drop Onto SFA Basket in Pool**

Fuel Type: Maximum PWR

Organ	Inhalation Dose (rem)	Dose Term for Regulation	Submersion Dose (rem)	Dose Term for Regulation	Sum of Inhalation and Submersion (rem)	Dose Term for Regulation
Gonad	2.60E-04		6.34E-05		3.23E-04	
Breast	2.60E-04		7.27E-05		3.32E-04	
Lung	2.60E-04		6.19E-05		3.21E-04	
R Marrow	2.60E-04		01-Feb		3.69E+04	
B Surface	2.60E-04		1.19E-04		3.79E-04	
Thyroid	1.94E-03	<MAX CDE	6.40E-05		2.00E-03	
Remainder	2.60E-04		5.91E-05		3.19E-04	
Whole Body	**3.10E-04**	<CEDE	**6.45E-05**	<DDE	**3.74E-04**	<TEDE=CEDE+DDE
Eye Lens	N/A		0.00E+00	<EYE		
Skin	N/A		7.16E-03	<SKIN		
					2.00E-03	<MAX CDE + DDE

The maximum organ inhalation dose (CDE) is to the Thyroid

Note: Bolded results are added together to calculate TEDE (CEDE + DDE)

RESULTS:

Dose Term	Offsite Dose (rem)
TEDE =	3.74E-04
Max. CDE + DDE =	2.00E-03
Eye =	0.00E+00
Skin =	7.16E-03

Dose Terms:
TEDE = total effective dose equivalent
CEDE = inhalation whole body
DDE = submersion whole body
CDE = maximum internal organ, inhalation

Summary of Inhalation and Submersion Dose Calculations

Event: **2-07** **Handling Equipment Drop Onto SFA Basket in Hot Cell**

Fuel Type: Maximum BWR

Organ	Inhalation Dose (rem)	Dose Term for Regulation	Submersion Dose (rem)	Dose Term for Regulation	Sum of Inhalation and Submersion (rem)	Dose Term for Regulation
Gonad	6.39E-04		4.57E-05		6.85E-04	
Breast	1.05E-03		5.24E-05		1.11E-03	
Lung	1.29E-02	<MAX CDE	4.47E-05		1.29E-02	<MAX CDE
R Marrow	1.21E-03		01-Feb		3.69E+04	
B Surface	3.23E-03		8.60E-05		3.32E-03	
Thyroid	2.33E-03		4.61E-05		2.38E-03	
Remainder	1.85E-03		4.26E-05		1.89E-03	
Whole Body	**2.73E-03**	<CEDE	**4.65E-05**	<DDE	**2.78E-03**	<TEDE=CEDE+DDE
Eye Lens	N/A		0.00E+00	<EYE		
Skin	N/A		5.16E-03	<SKIN		
					1.29E-02	<MAX CDE + DDE

The maximum organ inhalation dose (CDE) is to the Thyroid

Note: Bolded results are added together to calculate TEDE (CEDE + DDE)

RESULTS:

Dose Term	Offsite Dose (rem)
TEDE =	2.78E-03
Max. CDE + DDE =	1.29E-02
Eye =	0.00E+00
Skin =	5.16E-03

Dose Terms:
TEDE = total effective dose equivalent
CEDE = inhalation whole body
DDE = submersion whole body
CDE = maximum internal organ, inhalation

Summary of Inhalation and Submersion Dose Calculations

Event: **2-08** **Unsealed DC Collision**

Fuel Type: Maximum BWR

Organ	Inhalation Dose (rem)	Dose Term for Regulation	Submersion Dose (rem)	Dose Term for Regulation	Sum of Inhalation and Submersion (rem)	Dose Term for Regulation
Gonad	3.51E-03		2.52E-04		3.77E-03	
Breast	5.79E-03		2.88E-04		6.08E-03	
Lung	7.09E-02	<MAX CDE	2.46E-04		7.12E-02	<MAX CDE
R Marrow	6.68E-03		01-Feb		3.69E+04	
B Surface	1.78E-02		4.73E-04		1.82E-02	
Thyroid	1.28E-02		2.54E-04		1.31E-02	
Remainder	1.02E-02		2.34E-04		1.04E-02	
Whole Body	**1.50E-02**	<CEDE	**2.56E-04**	<DDE	**1.53E-02**	<TEDE=CEDE+DDE
Eye Lens	N/A		0.00E+00	<EYE		
Skin	N/A		2.84E-02	<SKIN		
					7.12E-02	<MAX CDE + DDE

The maximum organ inhalation dose (CDE) is to the Thyroid

Note: Bolded results are added together to calculate TEDE (CEDE + DDE)

RESULTS:

Dose Term	Offsite Dose (rem)
TEDE =	1.53E-02
Max. CDE + DDE =	7.12E-02
Eye =	0.00E+00
Skin =	2.84E-02

Dose Terms:
TEDE = total effective dose equivalent
CEDE = inhalation whole body
DDE = submersion whole body
CDE = maximum internal organ, inhalation

Summary of Inhalation and Submersion Dose Calculations

Event: **2-09** **Unsealed DC Drop and Slapdown**

Fuel Type: Maximum BWR

Organ	Inhalation Dose (rem)	Dose Term for Regulation	Submersion Dose (rem)	Dose Term for Regulation	Sum of Inhalation and Submersion (rem)	Dose Term for Regulation
Gonad	3.51E-03		2.52E-04		3.77E-03	
Breast	5.79E-03		2.88E-04		6.08E-03	
Lung	7.09E-02	<MAX CDE	2.46E-04		7.12E-02	<MAX CDE
R Marrow	6.68E-03		01-Feb		3.69E+04	
B Surface	1.78E-02		4.73E-04		1.82E-02	
Thyroid	1.28E-02		2.54E-04		1.31E-02	
Remainder	1.02E-02		2.34E-04		1.04E-02	
Whole Body	**1.50E-02**	<CEDE	**2.56E-04**	<DDE	**1.53E-02**	<TEDE=CEDE+DDE
Eye Lens	N/A		0.00E+00	<EYE		
Skin	N/A		2.84E-02	<SKIN		
					7.12E-02	<MAX CDE + DDE

The maximum organ inhalation dose (CDE) is to the Thyroid

Note: Bolded results are added together to calculate TEDE (CEDE + DDE)

RESULTS:

Dose Term	Offsite Dose (rem)
TEDE =	1.53E-02
Max. CDE + DDE =	7.12E-02
Eye =	0.00E+00
Skin =	2.84E-02

Dose Terms:
TEDE = total effective dose equivalent
CEDE = inhalation whole body
DDE = submersion whole body
CDE = maximum internal organ, inhalation

Summary of Inhalation and Submersion Dose Calculations

Event: **2-10** **Handling Equipment Drop Onto Unsealed DC**

Fuel Type: Maximum BWR

Organ	Inhalation Dose (rem)	Dose Term for Regulation	Submersion Dose (rem)	Dose Term for Regulation	Sum of Inhalation and Submersion (rem)	Dose Term for Regulation
Gonad	3.51E-03		2.52E-04		3.77E-03	
Breast	5.79E-03		2.88E-04		6.08E-03	
Lung	7.09E-02	<MAX CDE	2.46E-04		7.12E-02	<MAX CDE
R Marrow	6.68E-03		01-Feb		3.69E+04	
B Surface	1.78E-02		4.73E-04		1.82E-02	
Thyroid	1.28E-02		2.54E-04		1.31E-02	
Remainder	1.02E-02		2.34E-04		1.04E-02	
Whole Body	**1.50E-02**	<CEDE	**2.56E-04**	<DDE	**1.53E-02**	<TEDE=CEDE+DDE
Eye Lens	N/A		0.00E+00	<EYE		
Skin	N/A		2.84E-02	<SKIN		
					7.12E-02	<MAX CDE + DDE

The maximum organ inhalation dose (CDE) is to the Thyroid

Note: Bolded results are added together to calculate TEDE (CEDE + DDE)

RESULTS:

Dose Term	Offsite Dose (rem)
TEDE =	1.53E-02
Max. CDE + DDE =	7.12E-02
Eye =	0.00E+00
Skin =	2.84E-02

Dose Terms:
TEDE = total effective dose equivalent
CEDE = inhalation whole body
DDE = submersion whole body
CDE = maximum internal organ, inhalation

Summary of Inhalation and Submersion Dose Calculations

Event: **2-11** **Shipping Cask Drop Into Cask Preparation Pit**

Fuel Type: Maximum BWR

Organ	Inhalation Dose (rem)	Dose Term for Regulation	Submersion Dose (rem)	Dose Term for Regulation	Sum of Inhalation and Submersion (rem)	Dose Term for Regulation
Gonad	5.43E-03		3.89E-04		5.82E-03	
Breast	8.95E-03		4.45E-04		9.40E-03	
Lung	1.10E-01	<MAX CDE	3.80E-04		1.10E-01	<MAX CDE
R Marrow	1.03E-02		01-Feb		3.69E+04	
B Surface	2.75E-02		7.31E-04		2.82E-02	
Thyroid	1.98E-02		3.92E-04		2.02E-02	
Remainder	1.57E-02		3.62E-04		1.61E-02	
Whole Body	**2.32E-02**	<CEDE	**3.96E-04**	<DDE	**2.36E-02**	<TEDE=CEDE+DDE
Eye Lens	N/A		0.00E+00	<EYE		
Skin	N/A		4.39E-02	<SKIN		
					1.10E-01	<MAX CDE + DDE

The maximum organ inhalation dose (CDE) is to the Thyroid

Note: Bolded results are added together to calculate TEDE (CEDE + DDE)

RESULTS:

Dose Term	Offsite Dose (rem)
TEDE =	2.36E-02
Max. CDE + DDE =	1.10E-01
Eye =	0.00E+00
Skin =	4.39E-02

Dose Terms:
TEDE = total effective dose equivalent
CEDE = inhalation whole body
DDE = submersion whole body
CDE = maximum internal organ, inhalation

Summary of Inhalation and Submersion Dose Calculations

Event: **2-12** **Shipping Cask Drop Into Cask Unloading Pool**

Fuel Type: Maximum BWR

Organ	Inhalation Dose (rem)	Dose Term for Regulation	Submersion Dose (rem)	Dose Term for Regulation	Sum of Inhalation and Submersion (rem)	Dose Term for Regulation
Gonad	1.65E-03		3.89E-04		2.03E-03	
Breast	1.65E-03		4.45E-04		2.09E-03	
Lung	1.65E-03		3.80E-04		2.03E-03	
R Marrow	1.65E-03		01-Feb		3.69E+04	
B Surface	1.65E-03		7.31E-04		2.38E-03	
Thyroid	1.31E-02	<MAX CDE	3.92E-04		1.35E-02	
Remainder	1.65E-03		3.62E-04		2.01E-03	
Whole Body	**1.99E-03**	<CEDE	**3.96E-04**	<DDE	**2.39E-03**	<TEDE=CEDE+DDE
Eye Lens	N/A		0.00E+00	<EYE		
Skin	N/A		4.39E-02	<SKIN		
					1.35E-02	<MAX CDE + DDE

The maximum organ inhalation dose (CDE) is to the Thyroid

Note: Bolded results are added together to calculate TEDE (CEDE + DDE)

RESULTS:

Dose Term	Offsite Dose (rem)
TEDE =	2.39E-03
Max. CDE + DDE =	1.35E-02
Eye =	0.00E+00
Skin =	4.39E-02

Dose Terms:

TEDE = total effective dose equivalent

CEDE = inhalation whole body

DDE = submersion whole body

CDE = maximum internal organ, inhalation

Summary of Inhalation and Submersion Dose Calculations

Event: **NM-01** **Non-Mechanistic Shipping Cask Leak**

Fuel Type: Maximum BWR

Organ	Inhalation Dose (rem)	Dose Term for Regulation	Submersion Dose (rem)	Dose Term for Regulation	Sum of Inhalation and Submersion (rem)	Dose Term for Regulation
Gonad	1.65E-03		3.89E-04		2.03E-03	
Breast	1.65E-03		4.45E-04		2.09E-03	
Lung	1.65E-03		3.80E-04		2.03E-03	
R Marrow	1.65E-03		01-Feb		3.69E+04	
B Surface	1.65E-03		7.31E-04		2.38E-03	
Thyroid	1.31E-02	<MAX CDE	3.92E-04		1.35E-02	
Remainder	1.65E-03		3.62E-04		2.01E-03	
Whole Body	**1.99E-03**	<CEDE	**3.96E-04**	<DDE	**2.39E-03**	<TEDE=CEDE+DDE
Eye Lens	N/A		0.00E+00	<EYE		
Skin	N/A		4.39E-02	<SKIN		
					1.35E-02	<MAX CDE + DDE

The maximum organ inhalation dose (CDE) is to the Thyroid

Note: Bolded results are added together to calculate TEDE (CEDE + DDE)

RESULTS:

Dose Term	Offsite Dose (rem)
TEDE =	2.39E-03
Max. CDE + DDE =	1.35E-02
Eye =	0.00E+00
Skin =	4.39E-02

Dose Terms:

TEDE = total effective dose equivalent

CEDE = inhalation whole body

DDE = submersion whole body

CDE = maximum internal organ, inhalation

Summary of Inhalation and Submersion Dose Calculations

Event: **NM-02** **Non-Mechanistic Preclosure Early Failure of a WP**

Fuel Type: Maximum PWR

Organ	Inhalation Dose (rem)	Dose Term for Regulation	Submersion Dose (rem)	Dose Term for Regulation	Sum of Inhalation and Submersion (rem)	Dose Term for Regulation
Gonad	1.85E-03		4.51E-04		2.30E-03	
Breast	1.85E-03		5.17E-04		2.36E-03	
Lung	1.85E-03		4.40E-04		2.29E-03	
R Marrow	1.85E-03		01-Feb		3.69E+04	
B Surface	1.85E-03		8.48E-04		2.69E-03	
Thyroid	1.38E-02	<MAX CDE	4.55E-04		1.42E-02	
Remainder	1.85E-03		4.20E-04		2.27E-03	
Whole Body	**2.20E-03**	<CEDE	**4.59E-04**	<DDE	**2.66E-03**	<TEDE=CEDE+DDE
Eye Lens	N/A		0.00E+00	<EYE		
Skin	N/A		5.09E-02	<SKIN		
					1.42E-02	<MAX CDE + DDE

The maximum organ inhalation dose (CDE) is to the Thyroid

Note: Bolded results are added together to calculate TEDE (CEDE + DDE)

RESULTS:

Dose Term	Offsite Dose (rem)
TEDE =	2.66E-03
Max. CDE + DDE =	1.42E-02
Eye =	0.00E+00
Skin =	5.09E-02

Dose Terms:
TEDE = total effective dose equivalent
CEDE = inhalation whole body
DDE = submersion whole body
CDE = maximum internal organ, inhalation

Validation Test Cases for Formulas Contained in this Workbook

Worksheet	Cell Range	Test Cell	Formula	Input	Output	Hand-Calculated
Avg Dose	C68 to L68 & P68 to Y68	C68	=SUM(C66:C67)	C66=0, C67=0.489	C68=0.489	C68=0.489
Max Dose	C68 to L68 & P68 to Y68	C68	=SUM(C66:C67)	C66=0, C67=2.44	C68=2.44	C68=2.44
Crud	D7	D7	=IF(D3="y",5902*EXP(-LN(2)*D5/2.73),0)	D3=y, D5=5	D7=1658.3	D7=1658.297
Crud	D8	D8	=IF(D3="y",7415*EXP(-LN(2)*D5/2.73),0)	D3=y, D5=5	D8=2083.4	D8=2083.407
Crud	D9	D9	=140*EXP(-LN(2)*D5/5.271)*IF(Input!E18=1,1,0.5)	D5=5, Input!E18=24	D9=36.3	D9=36.270
Crud	D10	D10	=1254*EXP(-LN(2)*D5/5.271)*IF(Input!E18=1,1,0.5)	D5=5, Input!E18=24	D10=324.9	D10=324.874
Crud	B20	B20	=(D7*D12)/1000000	D7=1658.3, D12=449,003	B20=744.6	B20=744.582
Crud	B21	B21	=(D8*D13)/1000000	D8=2083.4, D13=168,148	B21=350.3	B21=350.320
Crud	B22	B22	=(D9*D12)/1000000	D9=36.3, D12=449,003	B22=16.3	B22=16.299
Crud	B23	B23	=(D10*D13)/1000000	D10=324.9, D13=168,148	B23=54.6	B23=54.631
Crud	B34 to I37	B34	=$D$9*$D$12*B$29*$B$16*$B$17	D9=36.3, D12=449,003, B29=4.76E-9, B16=3.7E4, B17=100	B34=2.87E5	B34=2.8705E5
Grouped Sources	C6 to J10	C6	=SUM(Groupings!C$7:C$9)	Groupings!(C7=3.02E4, C8=10.9, C9=0)	C6=3.02E4	C6=30210.9
RFs	H5:H12, H19:26	H5	=C5*D5*E5*F5*G5	C5=1, D5=0.3, E5=1, F5=1, G5=1	H5=0.30	H5=0.300
X-Q Values	C14, C20	C14	=C12-((B14-B12)/(B13-B12))*(C12-C13)	C12=3.1E-5, B14=8000, B12=7500, B13=10000, C13=2.29E-5	C14=2.94E-5	C14=2.938E-5
Submersion	G9 to G18	G9	=B9*C9*D9*E9*F9	B9=2.44, C9=24, D9=0.3, E9=1, F9=2.17E-5	G9=3.81E-4	G9=3.812E-4
Gonad	E8 to E12	E8	=IF(Input!$G$21=1,RFs!$H$26,RFs!$H$12)	Input!G21=24, RFs!H26=0, RFs!H12=1.50E-7	E8=1.50E-7	E8=1.50E-7
Gonad	I8 to I12	I8	=IF($C$8="N/A", 0, $C$8*$D$8*$E$8*$F$8*$G$8*$H$8)	C8=1.12E12, D8=24, E8=1.50E-7, F8=1.0, G8=3.30E-4, F8=2.17E-5	I8=2.88E-2	I8=0.0289
Breast, Lung, Marrow, Bone Sur, Thyroid, Remainder & Whole Body	E8 to E12	(same as formulas for Gonad)				
Breast, Lung, Marrow, Bone Sur, Thyroid, Remainder & Whole Body	I8 to I12	(same as formulas for Gonad)				
Summary	G14	G14	=C14+E14	C14=9.53E-1, E14=3.87E-4	G14=9.53E-1	G14=0.9534
Summary	G18	G18	=MAX(C7:C13)+E14	MAX=C11=4.09, E14=3.87E-4	G18=4.09	G18=4.0904

* Output values may differ slightly from hand calculations due to rounding errors. These differences are acceptable for the range of input values used in this calculation.

Attachment XI

Dose Comparison of MOX PWR SNF and Maximum PWR SNF

Dose Comparison of MOX PWR SNF and Maximum PWR SNF

Some quantity of commercial mixed oxide (MOX) fuel is expected to be received at the MGR. Therefore, a dose comparison between high-burnup MOX PWR fuel (DOE 1999) and Maximum PWR fuel (CRWMS M&O 1999h) was performed to quantify and assess the difference.

The Maximum PWR SFA inventories used in this comparison are the same as those used in the Category 2 dose calculations (Attachments VIII and X), based on *PWR Source Term Generation and Evaluation* (CRWMS M&O 1999h). The high-burnup MOX fuel inventories are based on Table A-43 of the *Draft Environmental Impact Statement (EIS) for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE 1999). The MOX fuel inventories are based on fuel with a five year cooling time, similar to the Maximum PWR fuel. A comparison of the nuclide activities for each of these fuels is provided in Figure 1.

Next, the offsite dose due to Event 2-09 (Unsealed DC Drop and Slapdown)(Attachment VII) was calculated using the MOX fuel source term and compared to the same event using Maximum PWR fuel. The calculation methodology (Section 2.2 of the calculation document) and input parameters (other than source term) were held constant for both cases. The input parameters are listed in Figure 2.

The summary results for the MOX fuel case are shown in Figure 3 and for the Maximum PWR case in Figure 4. The TEDE dose at 11-km for Event 2-09 is 1.03×10^{-2} rem for Maximum PWR fuel and 9.12×10^{-3} rem for high-burnup MOX fuel, a decrease of 11.5% for the MOX fuel. A complete summary and comparison of the results is shown in Table 1 below:

Table 1 – Comparison of Dose Results for Event 2-09
Using Maximum PWR Fuel and High-Burnup MOX Fuel

Event No.	Description / Fuel Type	Skin Dose (rem)	Max Organ Dose (rem)	Offsite TEDE Dose (rem)
2-09	Unsealed DC Drop and Slapdown / **Maximum PWR Fuel**	3.76×10^{-2}	3.74×10^{-2}	1.03×10^{-2}
2-09	Unsealed DC Drop and Slapdown / **High-Burnup MOX Fuel**	1.74×10^{-2}	3.51×10^{-2}	9.12×10^{-3}
	% Difference:	54%	6%	12%

The result of this comparison is that Maximum PWR fuel is more conservative for Category 2 offsite dose calculations compared to high-burnup MOX fuel. MOX fuel resulted in a 54% lower skin dose, 6% lower maximum organ (lung) dose, and 12% lower TEDE dose.

The following files were used to perform the comparisons in this attachment: (1) SR Source Terms_MOX_Rev01.xls for the high-burnup MOX source terms, (2) SR Source Terms_Rev01.xls for the Maximum PWR source terms, (3) SR Cat. 2 TEDE Dose_MOX_Rev01.xls for the MOX fuel dose calculations, and (4) SR Cat. 2 TEDE

Dose_Rev01.xls for the Maximum PWR dose calculations. Each of these electronic files is contained on floppy disk and described in Attachment I.

Nuclide	MOX Curies/FA (DOE 1999)	CSNF Curies/FA (CRWMS M&O 1999h)	% Difference
Ac-227	N/A	0.00E+00	N/A
Am-241	2.5E+03	8.71E+02	187.0%
Am-242m	4.9E+01	1.02E+01	380.4%
Am-243	5.6E+01	5.22E+01	7.3%
C-14	5.4E-01	4.89E-01	10.4%
Cd-113m	N/A	3.82E+01	N/A
Cl-36	N/A	9.69E-03	N/A
Cm-242	1.0E+02	3.43E+01	191.5%
Cm-243	8.5E+01	3.83E+01	121.9%
Cm-244	8.9E+03	1.12E+04	-20.5%
Cm-245	N/A	1.41E+00	N/A
Cm-246	N/A	8.38E-01	N/A
Co-60	2.4E+03	5.66E+03	-57.6%
Cs-134	2.5E+04	3.72E+04	-32.8%
Cs-135		5.99E-01	--
Cs-137	7.0E+04	9.87E+04	-29.1%
Eu-154	N/A	5.77E+03	N/A
Eu-155	N/A	1.68E+03	N/A
Fe-55	N/A	6.84E+02	N/A
H-3	2.9E+02	4.72E+02	-38.6%
I-129	3.0E-02	3.38E-02	-11.2%
Kr-85	2.6E+03	5.63E+03	-53.8%
Nb-93m	3.9E+01	4.54E+01	-14.1%
Nb-94	9.8E-01	1.27E+00	-22.8%
Ni-59	1.7E+00	2.78E+00	-38.8%
Ni-63	2.3E+02	4.16E+02	-44.7%
Np-237	N/A	3.85E-01	N/A
Pa-231	N/A	4.25E-05	N/A
Pb-210	N/A	0.00E+00	N/A
Pd-107	N/A	1.45E-01	N/A
Pm-147	N/A	2.34E+04	N/A
Pu-238	2.7E+03	6.16E+03	-56.2%
Pu-239	4.6E+02	1.85E+02	148.6%
Pu-240	8.8E+02	3.90E+02	125.6%
Pu-241	2.2E+05	7.91E+04	178.1%
Pu-242	N/A	3.01E+00	N/A
Ra-226	N/A	0.00E+00	N/A
Ra-228	N/A	0.00E+00	N/A
Ru-106	1.8E+04	1.27E+04	41.7%
Sb-125	N/A	2.05E+03	N/A

Figure 1 – Source Term Comparison of MOX and Maximum PWR CSNF

Nuclide	MOX Curies/FA (DOE 1999)	CSNF Curies/FA (CRWMS M&O 1999h)	% Difference
Se-79	N/A	6.95E-02	N/A
Sm-147	N/A	0.00E+00	N/A
Sm-151	5.4E+02	3.13E+02	72.5%
Sn-126	N/A	6.28E-01	N/A
Sr-90	2.4E+04	6.30E+04	-61.9%
Tc-99	N/A	1.28E+01	N/A
Th-229	N/A	0.00E+00	N/A
Th-230	N/A	3.56E-05	N/A
Th-232	N/A	0.00E+00	N/A
U-232	N/A	5.31E-02	N/A
U-233	N/A	2.42E-05	N/A
U-234	6.8E+02	5.46E-01	124442.1%
U-235	6.7E-04	4.15E-03	-83.9%
U-236	7.7E-03	2.24E-01	-96.6%
U-238	1.5E-01	1.43E-01	4.9%
Zr-93	N/A	1.33E+00	N/A

Figure 1 – Source Term Comparison of MOX and Maximum PWR CSNF (continued)

Input Parameters for Category 2 Dose Calculations

Fuel Type:		
Average PWR / Average BWR / Maximum PWR / Maximum BWR	High-Burnup MOX Fuel	
Event #:	2-09	
Event Description:	Unsealed DC Drop and Slapdown	
Event Frequency:	8.40E-03	(Note 6)
Number of Fuel Assemblies Damaged:	21	(Note 1)
Does the Event Occur in a Pool?		
Yes / No		
HEPA Mitigation Factor:		
HEPA Filtration	0.01	Particulate Release (Note 3)
No HEPA Filtration	1.0	Gas Release (Note 3)
Maximum Sector Acute X/Q: Distance (m):		
5,000 / 8,000 / 11,000	2.17E-05	(Note 2)
Breathing Rate (m^3/sec)	3.3E-04	(Note 4)
Ground Release?	Y	(Note 5)

Note 1:	Number of fuel assemblies determined according to Assumption 3.19.
Note 2:	Acute releases are assumed for all Cat. 2 calculations. See "X-Q Values" worksheet for X/Q details.
Note 3:	HEPA filters, if available, are 99% effective in retaining particulates and volatiles (Cs) (Assumption 3.23). 100% of the Noble gases are released.
Note 4:	Breathing rate based on Standard Review Plan for Dry Cask Storage Systems, NUREG-1536. Based on acute exposures to "reference man."
Note 5:	Ground release is conservatively assumed for Cat. 2 calculations; using a stack release will typically result in a lower offsite dose (Assumption 3.25).
Note 6:	A non-mechanistic release was assumed without a frequency analysis. Sealed cask and WP breaches are assumed to be beyond design basis events (Assumption 3.15).

Blue shading = calculated fields

Yellow shading = input fields

Figure 2 – Input Parameters

Summary of Inhalation and Submersion Dose Calculations						
Event:	2-09	Unsealed DC Drop and Slapdown				
Fuel Type:	High-Burnup MOX Fuel					
Waste form	Inhalation Dose (rem)	Dose Term for Regulation	Submersion Dose (rem)	Dose Term for Regulation	Sum of Inhalation and Submersion (rem)	Dose Term for Regulation
Gonad	1.87E-03		1.54E-04		2.02E-03	
Breast	2.70E-03		1.76E-04		2.87E-03	
Lung	3.49E-02	<CDE	1.50E-04		3.51E-02	<CDE
R Marrow	4.21E-03		1.43E-04		4.35E-03	
B Surface	2.16E-02		2.89E-04		2.19E-02	
Thyroid	2.60E-03		1.55E-04		2.75E-03	
Remainder	5.38E-03		1.43E-04		5.52E-03	
Whole Body	**8.96E-03**	<CEDE	**1.56E-04**	<DDE	9.12E-03	<TEDE=CEDE+DDE
Eye Lens	N/A		0.00E+00	<EYE	0.00E+00	<EYE
Skin	N/A		1.74E-02	<SKIN	1.74E-02	<SKIN
					3.51E-02	<CDE + DDE
The maximum organ inhalation dose (CDE) is to the Lung						
Note: Bolded quantities are added together to calculate TEDE (CEDE + DDE)						
RESULTS:						

Dose Term	Offsite Dose (rem)
TEDE = CEDE + DDE =	9.12E-03
Max. CDE + DDE =	3.51E-02
Eye =	0.00E+00
Skin =	1.74E-02

CEDE = inhalation whole body
DDE = submersion whole body
CDE = maximum internal organ, inhalation

Figure 3 - Dose Results for MOX Fuel

	Summary of Inhalation and Submersion Dose Calculations					
Event:	2-09	Unsealed DC Drop and Slapdown				
Fuel Type:	Maximum PWR					
Waste form	Inhalation Dose (rem)	Dose Term for Regulation	Submersion Dose (rem)	Dose Term for Regulation	Sum of Inhalation and Submersion (rem)	Dose Term for Regulation
Gonad	3.65E-03		3.33E-04		3.99E-03	
Breast	4.45E-03		3.81E-04		4.83E-03	
Lung	3.71E-02	<CDE	3.25E-04		3.74E-02	<CDE
R Marrow	5.89E-03		3.10E-04		6.20E-03	
B Surface	2.20E-02		6.26E-04		2.27E-02	
Thyroid	1.31E-02		3.36E-04		1.34E-02	
Remainder	7.18E-03		3.10E-04		7.49E-03	
Whole Body	**9.95E-03**	<CEDE	**3.39E-04**	<DDE	**1.03E-02**	<TEDE=CEDE+DDE
Eye Lens	N/A		0.00E+00	<EYE	0.00E+00	<EYE
Skin	N/A		3.76E-02	<SKIN	3.76E-02	<SKIN
					3.74E-02	<CDE + DDE
The maximum organ inhalation dose (CDE) is to the Lung						
Note: Bolded results are added together to calculate TEDE (CEDE + DDE)						
RESULTS:						

Dose Term	Offsite Dose (rem)
TEDE = CEDE + DDE =	1.03E-02
Max. CDE + DDE =	3.74E-02
Eye =	0.00E+00
Skin =	3.76E-02

Dose Terms:
CEDE = inhalation whole body
DDE = submersion whole body
CDE = maximum internal organ, inhalation

Figure 4 - Dose Results for Maximum PWR Fuel